

Final Report Reduction and Analysis of ATS-6 Data (1 November 1976—31 October 1977)

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Prepared by G. A. PAULIKAS and J. B. BLAKE
Space Sciences Laboratory

10 November 1977



Prepared for
NASA GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Contract No. NAS5-23788



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THE AEROSPACE CORPORATION
El Segundo, California

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REDUCTION AND ANALYSIS OF ATS-6 DATA
(1 November 1976 - 31 October 1977)

Prepared by
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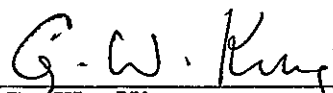


G. A. Paulikas, Director
Space Sciences Laboratory



J. B. Blake, Head
Space Particles and Fields
Department

Approved



G. W. King
Vice President and General Manager
The Ivan A. Getting Laboratories

ACKNOWLEDGMENTS

We thank Henry Hilton for the invaluable contributions he has made in perfecting and maintaining the ATS-6 reduction and analysis software. Production of ATS-6 was handled by Doretha (Ross) Mayfield and Vera Bledsoe.

ABSTRACT

Results obtained from the analysis of data returned by the Aerospace Corporation energetic particle spectrometer on ATS-6 are presented. The work reported here emphasizes study of the energetic electron environment and the effects of the solar wind parameters on the energetic electrons trapped at the synchronous altitude.

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I. Introduction

This report summarizes the work performed under NASA Contract NAS5-23788 at The Aerospace Corporation. The tasks performed under this contract consisted of the reduction of data obtained by The Aerospace Corporation experiment on ATS-6 and of scientific analysis of the data.

During the period covered by this contract we have reduced virtually all (>95%) of the data obtained by our experiment during 1974, 1975 and 1976. Data covering the first half of 1977 have also been reduced. These data have been used to develop a description of the energetic electron environment at the synchronous altitude in the 1974-1977 interval. We have also used ATS-5 data (obtained from Dr. C. E. McIlwain of UCSD) to extend our overview of the energetic electron population of the synchronous orbit back to 1969.

We have also continued our analysis of the effects of variations of the solar wind parameters on the energetic electron population. In this connection we have acquired the data sets required for correlative studies from various sources, including NSSDC.

A plan for transfer of ATS-6 data has been developed, coordinated with NSSDC and is being implemented.

Each of these efforts is described below.

II. Progress in Data Reduction

A. ATS-6 Data Reduction

Data reduction activities proceeded smoothly during FY 77, interrupted occasionally by the inevitable machine hardware and systems software problems. First pass reduction of data between Day 165, 1974 and Day 120, 1977 was completed by July 1977. We then returned to attempt to process the days of data (in 1974 and 1975) which had resisted reduction on the first try. This sub-project was completed by early September 1977, with the result that we believe we have reached the point of diminishing returns with all but 6 and 4 days of data processed for 1974 and 1975, respectively. In September 1977 we resumed mass processing of data obtained during 1977 with the result that at the time of writing, we have processed most of the 1977 data through Day 180.

Appendix A contains a listing of the days of data processed.

B. ATS-1 Data Reduction

The ATS-1 spacecraft, stationed at 150°W contains an experiment (developed by Aerospace) which measures the fluxes of energetic electrons above energy thresholds similar to those of our ATS-6 experiment. The Aerospace ATS-1 experiment continues to be operational and data have been acquired from this experiment during several time intervals: mid-1974 - during the initial operations of ATS-6, early-to-middle 1975, during the move of ATS-6 from 94°W to 35°E longitude and in late 1976, during the return of ATS-6 from 35°E to 140°W .

Although preliminary reduction of all ATS-1 data obtained in 1974 and 1975 has been completed, we find that the data presentation formats are inconvenient for easy comparison of ATS-1 data with ATS-6 data. Accordingly we are modifying the ATS-1 data reduction program to be compatible in output with the ATS-6 software. With this modification, we expect to be able to normalize the ATS-1 data to the ATS-6 results and

then be able to perform an unambiguous determination of the variation of energetic electron fluxes with spacecraft longitude (really magnetic latitude). In addition, with the retrieval of our 1966-1968 ATS-1 data deposited with NSSDC the combined ATS-1,ATS-5 and ATS-6 data sets will give us coverage of the energetic electron environment from 1966 through 1977.

C. Utilization of ATS-5 Data

The ATS-5 spacecraft, launched in 1969 and stationed at 105°W contains an experiment (developed by UCSD) which measures energetic electrons above several energy thresholds. The measurements made by ATS-5 are in many respects similar to the ATS-6 data. We have obtained a copy of a tape from Dr. C. E. McIlwain which contains the daily average fluxes of electrons (and solar protons) above several thresholds observed by ATS-5 from mid-1969 to early 1972. In addition, ATS-5 was turned on in mid-1974 during the early operation of ATS-6. It is thus possible to normalize these data sets and thus obtain an overview of the behavior of the energetic electrons at synchronous during a major fraction of the solar cycle. We have developed a program to present the UCSD ATS-5 data in a format compatible with the ATS-6 presentation. Figure 1 shows a sample of the ATS-5 results.

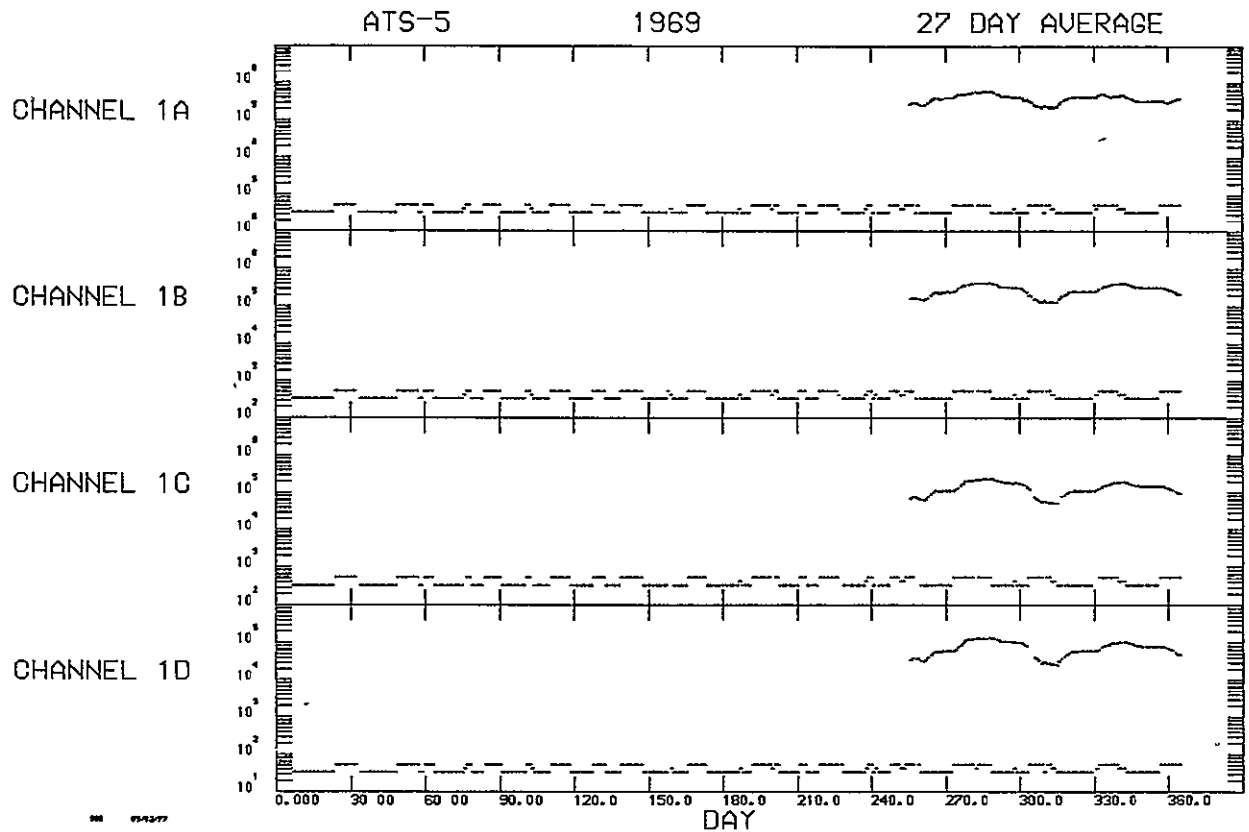


Figure 1. Running 27-day averages of four channels of ATS-5 data for 1969 presented in a format identical to ATS-6 data presentation. Trace at bottom of each panel indicates polarity of interplanetary magnetic field. Similar data plots have been prepared for 1970, 1971 and portions of 1972 and 1974.

III. Scientific Analysis

A. Energetic Electrons at the Synchronous Altitude 1969-1977

1. Analysis of ATS-6 Data

Appendix B contains a report which describes the analysis we have carried out to date on the ATS-6 data in order to develop a picture of the behavior of the energetic electrons during the period of near solar minimum - the years 1974-1977.

2. Merging of ATS-5 and ATS-6 Data

The ATS-5 data, briefly mentioned earlier, has been combined with the ATS-6 data to give an overview of the properties of the energetic electron population at the synchronous orbit since 1969. Recall that the last maximum of solar activity, as measured by the Zurich sunspot number, occurred in 1969, with the subsequent minimum in the solar cycle estimated to have occurred in mid-1976. Thus the combination of ATS-5 and ATS-6 data, shown in Figure 2 cover more than half of a solar cycle, with only a two year data gap between mid-1972 and mid-1974. Several qualitative conclusions can be drawn from an examination of Figure 2.

- a. There does not appear to be any major variations of the energetic electron radiation correlated with the solar cycle, although small, (less than a factor of two) effects may well be present.
- b. The range of the variability of the electron fluxes is more or less constant as a function of solar activity. For example, a factor of 50 peak-to-peak excursions in the running 27-day average E4 (≥ 3.9 Mev) flux are evident in the ATS-6 data as well as in the comparable ATS-5 channel.

B. Effects of Solar Wind Parameters on the Energetic Electron Population

Last year we reported finding a substantial variability of the energetic electron fluxes which was correlated with the passage of the sectors of the interplanetary

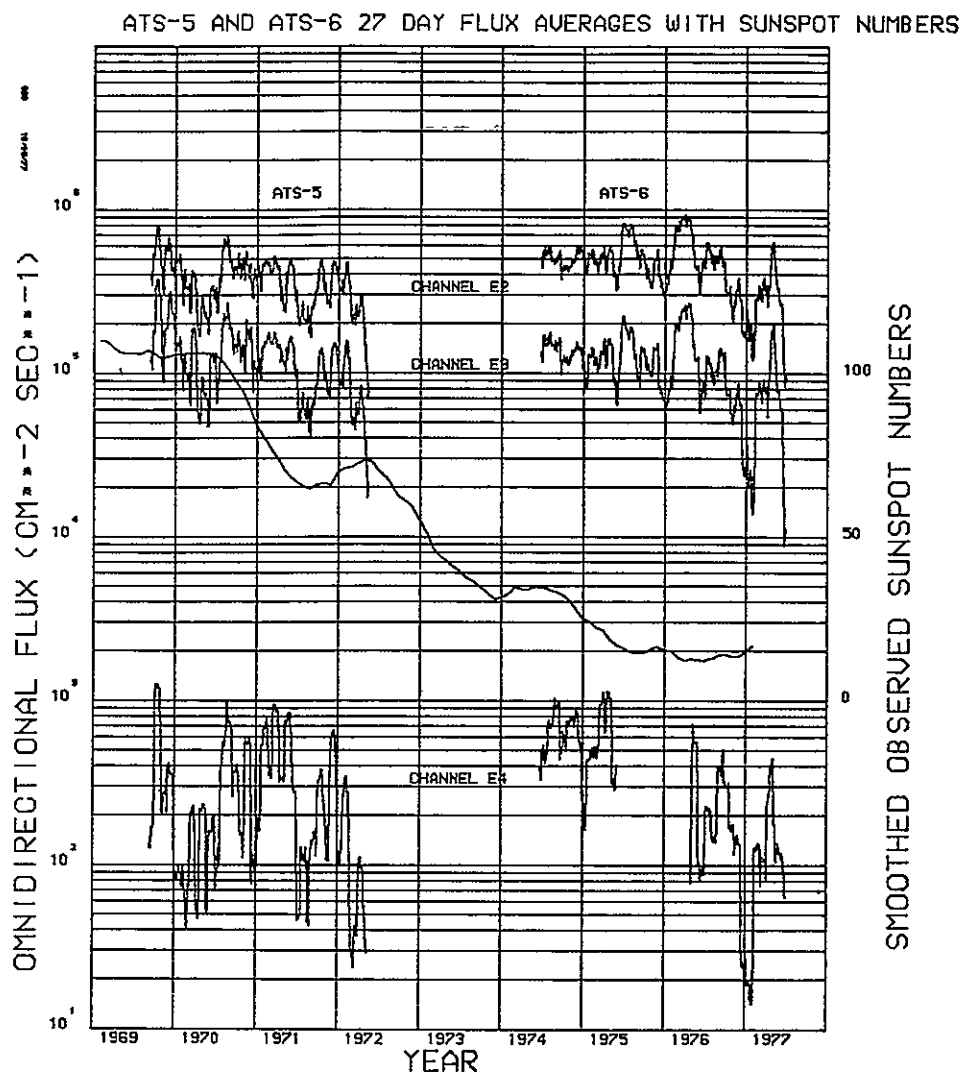


Figure 2. ATS-6 data and ATS-5 data (normalized to ATS-6 using the data overlap in 1974) on omnidirectional electron fluxes are plotted versus time. The data are running 27-day averages of fluxes $E2 \geq 0.7$ MeV, $E3 \geq 1.55$ MeV and $E4 \geq 3.9$ MeV. Also shown are the smoothed monthly sunspot numbers.

magnetic field past the earth. In FY 77 we have continued studying this phenomenon using the now much larger data base available to us and have expanded the study to include correlation of the energetic electron fluxes with other parameters of the solar wind, for example the solar wind velocity. In order to perform such correlations we have acquired from NSSDC, LASL and MIT data on the solar wind plasma covering the periods of interest. We are now proceeding with such correlation analysis.

A preliminary result is illustrated in Figure 3 where we have superimposed a plot of the solar wind velocity (delayed by $1\frac{1}{2}$ days) on a plot of the energetic electron fluxes. This plot clearly illustrates the very close correlation between solar wind velocity and energetic electron fluxes, if a "generation time" of $1\frac{1}{2}$ days is postulated.

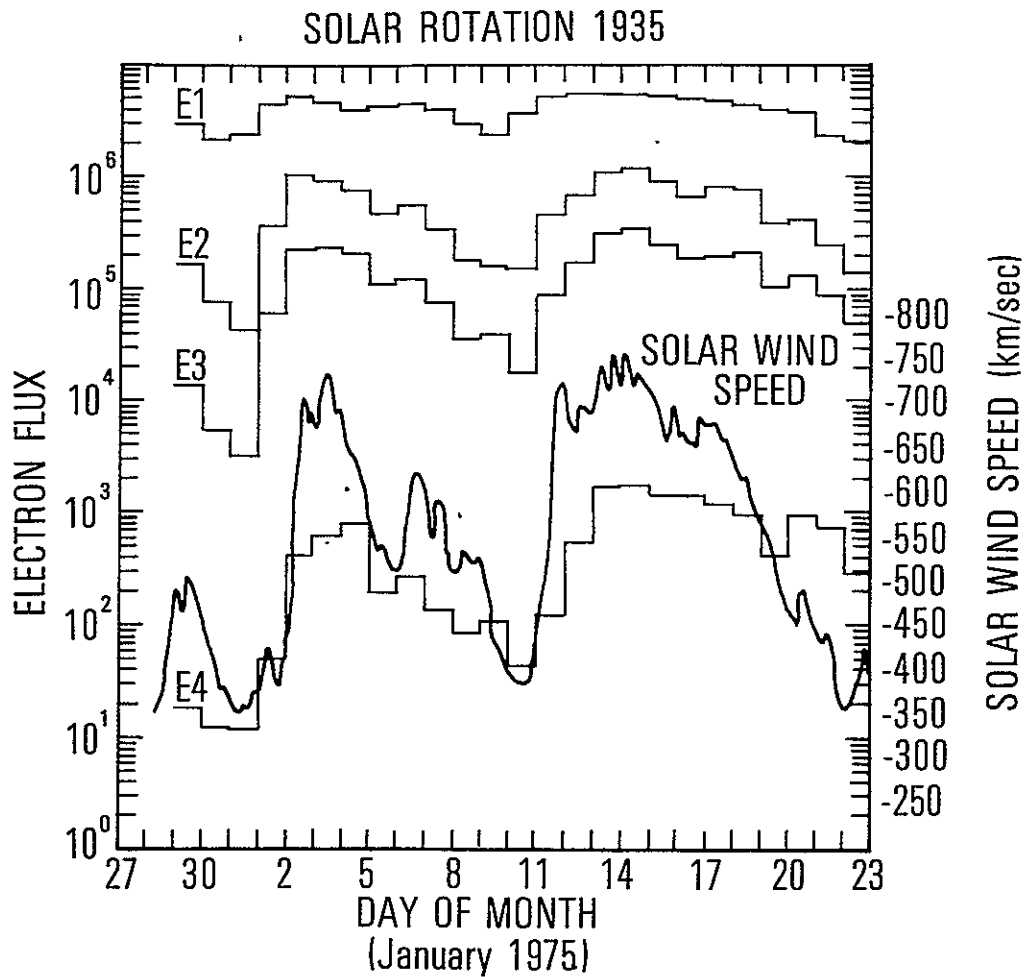


Figure 3. Energetic electron fluxes ($150 \text{ Kev} \leq E1 \leq 600 \text{ Kev}$, $E2 \geq 0.7 \text{ Mev}$, $E3 \geq 1.55 \text{ MeV}$ and $E4 \geq 3.9 \text{ MeV}$) and solar wind speed (delayed by 1.5 days) plotted as a function of time for solar rotation 1935. Trace at bottom of page indicates polarity of interplanetary magnetic field.

IV. Transfer of Data to NSSDC

We have prepared a plan for submission of our data to NSSDC. Briefly, we plan to transfer hourly averages of our data in blocks ordered by calendar year. In preparation for this transfer we have already completed processing all data for 1974 that can be processed with reasonable effort. All 1974 hourly average data has been inspected and bad data points, mis-identified days and other anomalies have been edited out or corrected. We expect that the 1974 data can be transferred to NSSDC by November, 1977 with the 1975 and 1976 data following at approximately monthly intervals.

In addition to transferring the hourly averaged data, we also plan to transfer approximately one hundred days of typical ATS-6 data in a format which contains the highest time resolution ($\Delta t = 1$ sec) contained in our measurements. The data tape format for these data tapes has been coordinated with NSSDC.

We are preparing a "Users Guide to Aerospace Corp. ATS-6 Data." This document, to be included in the transfer to NSSDC, contains description of the experiment, the data reduction and analysis procedures we use, descriptions of the several formats of data tapes, listing of experiment and data anomalies as well as a compilation of papers and reports resulting from the ATS-6 data.

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APPENDIX A

Summary of ATS-6 Data Processed

FORMAT OF PRESENTATION

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Sequence Number	NASA Tape Number	Date Data Processed	Day Number	Month	Day	Year

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22869	004400	08/30/76	94	4	4	1975
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22871	004400	08/30/76	96	4	6	1975
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APPENDIX B

Energetic Electrons at the Synchronous Altitude 1974-1977

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Abstract

A description of the energetic (140 kev to > 3.9 Mev) electron environment observed at the synchronous altitude during the 1974-1977 time interval is presented. These results were obtained by an experiment carried on the geostationary ATS-6 spacecraft. Observations were made at several longitudes. Electron fluxes exhibit a complex temporal behavior ranging in time scale from a diurnal variation to a semi-annual variation. Average fluxes are computed and compared with earlier studies and models.

Energetic Electrons at the Synchronous Altitude 1974-1977

I. Introduction

The synchronous orbit, because of its obvious utility for terrestrial applications, is undoubtedly the single most heavily populated orbit in space. Many spacecraft, spread over longitude, are in this orbit today, and the plans of various nations (Ref. 1, Ref. 2) emphasize an even heavier utilization of it for future communications, earth observations, meteorology, and data relay spacecraft. It is clear that the investment in such space systems is likely to run into the billions of dollars.

The premium on a precise, quantitative understanding of the space environment and the impact of the environment on space systems is enormous. Even savings of fractions of a percent, derived as a result of better information regarding the energetic radiation (for example, extending the life of a spacecraft and thus decreasing the replenishment rate) translate directly into savings which run into the tens of millions of dollars.

The purpose of this report is to summarize, in a format useful to the designers and operators of synchronous orbiting of space systems, the observations of energetic electrons at the synchronous altitude made by The Aerospace Corporation particle spectrometer flown on the ATS-6 spacecraft. Preliminary results have been reported in a series of internal reports (Refs. 3-8). In this report we shall concentrate on defining the average properties of the electron population as it existed in the 1974-1977 time interval at the synchronous orbit. Thus this report can be viewed as a sequel to earlier work (Refs. 9-12) which treated the properties of the particle population at the synchronous orbit during earlier epochs. It seems useful to begin by describing some of the salient features of the ATS-6 observing program which we conducted and to point out how the present data and results may be similar to, or differ from, earlier work because of differences in epoch, instrumentation, spacecraft orientation and the location of the spacecraft in longitude.

The observations described here were made between mid-1974 and early 1977. This time interval straddled to solar minimum (as defined by sunspot number) (Fig. 1). In contrast, earlier observation of energetic radiation at the synchronous orbit made by

instruments aboard ATS-1 and ATS-5 were made during times near the peak of solar activity: late 1966 to early 1968 in the case of ATS-1 and mid 1969 to early 1972 in the case of ATS-5. As is well known, the magnetosphere is relatively more quiescent during periods of low solar activity as contrasted to the time period near solar maximum. As we shall see below, periodic manifestations of solar-wind magnetosphere interactions emerge prominently in the ATS-6 data; in contrast, impulsive solar events which occur at frequent intervals during solar maximum and tend to mask the more regular features of magnetospheric dynamics are infrequently observed in the present data set. The ATS-6 data is thus unique because it represents the first observations of the particle populations of the synchronous orbit made during the interval near solar minimum.

The instrumentation used to obtain our data has been described elsewhere (Ref. 13); a brief summary of the relevant features is given in Appendix A. Briefly, we measured the directional fluxes of electrons in the 140-600 keV interval and the omnidirectional fluxes above thresholds of 700 keV, 1.55 MeV and 3.9 MeV. Energetic proton data were also obtained (during solar proton events; these data are not discussed here).

The ATS-6 was earth oriented so that the axes of the detectors were pointed radially outward along the earth-satellite line. Thus the (directional) 140-600 keV channel (E1) measured only one segment of the angular distribution, the precise segment depending on the (rather variable) orientation of the local magnetic field with respect to the detector axis. The omnidirectional fluxes (E2, E3, E4) obtained from the ATS-6 data were obtained from countrates registered by particles which could reach the detectors through a 2π steradian acceptance angle looking out along the earth-satellite line. In contrast, on ATS-1, for example, the rapid spin of the spacecraft coupled with a relatively slow count accumulation time served to form a true average of the in situ radiation.

During the period covered by our data, the ATS-6 spacecraft was moved several times to different longitudes. Because the geographic equator does not coincide everywhere with the geomagnetic equator, a spacecraft at the synchronous orbit may be at significantly different magnetic latitudes, depending on the longitude at which the spacecraft is stationed. ATS-6 observations began while the spacecraft was on the

equator at 94°W , where the magnetic latitude is about 11° . Subsequently the spacecraft was moved to 35°E and finally to 140°W . At both of these locations the magnetic equator is nearly coincident with the geographic equator.

The displacement of the spacecraft as little as 11° off the magnetic equator has a significant effect on the observations. We find that the geomagnetic field may quite often, particularly near local midnight, assume a configuration with a strong radial component, i.e. the magnetic field at $6.6 R_e$ appears, at these times, to assume a configuration expected to be found near the magnetotail. Such tail-like configurations are characterized by the absence of very energetic electrons. The fluxes observed at 94°W , i.e. somewhat off the magnetic equator, exhibit a significantly more dynamic behavior on the timescale of a day than seen at the magnetic equator where the geomagnetic field exhibits a more regular behavior, however, the long-term average fluxes do not reflect a very significant longitudinal difference. Spacecraft longitude is taken as a parameter in the data analysis, although, as we shall see below, temporal variations in the average particle fluxes are considerably larger than effects due to change in longitude.

For the purposes of this report, we have formed hourly averages, centered on the half hour, of all the electron data presently available to us. These hourly averages are the basic material from which further analysis proceeds. Daily averages, running 27 day averages, probability distributions are all formed from hourly averages.

II. Overview of the Observations

Figures 2 through 5 give an overview of the observations of energetic electrons from mid 1974 through early 1977. Plotted here are daily averages of the electron fluxes, together with data on the sector structure of the interplanetary magnetic field as a function of time. The location in longitude of ATS-6 and the periods of spacecraft movement are indicated on the figures and separately summarized in Table I.

The dynamic nature of the energetic electron fluxes, particularly at the higher energies, is immediately apparent. The dominant periodicity (in addition to the diurnal variations (see Refs. 11 and 15) which is not visible on a plot of daily averages) is the

TABLE I
ATS-6 Geographic and Geomagnetic Locations

Time Interval	Geographic Longitude	Magnetic Latitude*
Day 165, 1974-140, 1975	94°W	11°
Day 140, 1975-180, 1975	In transit	—
Day 180, 1975-214, 1976	35°E	5°
Day 214, 1976-330, 1976	In transit	—
Day 330, 1976-present	140°W	0°

* Derived from UCLA ATS-6 Magnetometer Data
(Courtesy R. L. McPherron)

strong modulation of the energetic electron fluxes on a timescale corresponding to the solar rotation period as well on a timescale consistent with either a two- or four-sector structure of the interplanetary field. (The effects of the interplanetary sector structure on the energetic particle population has been discussed previously in Ref. 11.).

It will be immediately appreciated by the reader that long term averages of these data, used for the purposes of accurate estimates of the radiation environment, must be approached with caution because of the large variation in the fluxes occurring on several timescales.

If we now form 27-day running averages of the data presented above, we obtain Figure 6 through 9. In these figures we again see the strong effects of solar rotation-to-rotation variability of the electron fluxes. This effect is particularly noticeable in the data for the more energetic electrons and stands out particularly well in late 1976 - early 1977. Also visible is a semi-annual variation in the energetic electron fluxes, with a maxima found near the equinoxes and minima near the solstices. To be sure, the moves of the spacecraft complicate the determination of the amplitude of this variation but it appears that the semi-annual variation is comparable to, if not greater than, the longitudinal effect. The semi-annual variation in the electron flux is presumably but a reflection of the well known semi-annual variation in geomagnetic activity (Ref. 17).

III. Average Fluxes and $P(F > F_x)$ Distributions

Using the data base discussed above, we have computed the probability distributions $P(F)$ and $P(F > F_x)$ in a manner analogous to that first described by in Ref. 18. $P(F > F_x)$ is the probability of observing a flux greater than F_x for some particular energy threshold, while $P(F)$ is the differential probability distribution. These curves have been computed for the several time intervals of interest and are presented as Figs. 10 through 15. Also computed, and indicated on the figures are u , the mean of $\log_{10} F$, J , the $\log_{10}$ of the mean flux and s , the standard deviation about u . Note, from the $P(F)$ curves that the distribution is not necessarily gaussian in $\log_{10} F$, in contrast to assumptions made in analyses of earlier data sets.

Table II summarizes the data presented in Figs. 10-15, while Fig. 16 presents spectra of the average flux for the various longitudes and time intervals covered by our data, together with the spectrum predicted by the AE-4 model (Ref. 9, 10). The points noted below can serve as a summary of our findings.

1. At energies greater than about 1.5 Mev, the ATS-6 data indicate the presence of a somewhat harder electron spectrum than the AE-4 model would predict. At energies below ≈ 1.5 Mev, our data indicate, in general, fewer electrons than AE-4. These conclusions are, however, tempered by the fact that the electron fluxes are highly variable and one can find significant time intervals (for example the late 1966 - early 1967 interval illustrated in Figs. 14 and 15) where the spectral shape at the higher energies approached that which one might expect from AE-4.
2. Longitudinal effects (caused by differences in magnetic latitude) in the mean flux are relatively minor. This conclusion must be tempered by the fact that no systematic analysis of simultaneous observations made at several longitudes has yet been carried out. There is some limited evidence (based on ATS-1/ATS-6 comparisons, Refs. 3, 12) that longitudinal flux differences ($150^{\circ}\text{W}/94^{\circ}\text{W}$) may be as large as a factor of two.
3. Although the mean fluxes observed may not be similar, the probability distributions $P(F > F_x)$ differ show systematic differences because there are far more flux dropouts off the equator. The differences are significant only near the $P(F > F_x) \approx 1$ axis.

IV. Diurnal Variations

It is of interest to compare the diurnal variations observed at the several longitudes and at the several particle energies. The mean flux for the three available longitudes is presented in Fig. 17, 18, 19 as a function of local time. As had been found previously (Ref. 11), the diurnal variation is larger at the higher electron energies. There does not seem to be any significant systematic change of the diurnal variation with longitude.

TABLE II
 COMPARISON OF ATS-6 DATA AND AE-4 MODEL
 MEAN FLUX ($\text{cm}^{-2}\text{sec}^{-1}$)

Energy	ATS-6				AE-4
	$94^{\circ}\text{W}, \lambda_M \approx 11^{\circ}$	$35^{\circ}\text{E}, \lambda_M \approx 0^{\circ}$		$140^{\circ}\text{W}, \lambda_M \approx 0^{\circ}$	
	Day 166, 74-Day 140, 75	Day 180, 75-Day 214, 76	Day 137, 76-Day 210, 76	Day 330, 76-Day 120, 77	
$> 140 \text{ keV}$	5.35×10^6	5.29×10^6	4.84×10^6	4.16×10^6	$1.66 \times 10^7 (> 150 \text{ keV})$
$> 700 \text{ keV}$	5.01×10^5	5.50×10^5	4.17×10^5	2.45×10^5	1.76×10^6
$> 1.55 \text{ MeV}$	1.32×10^2	1.35×10^5	7.76×10^4	5.37×10^4	1.75×10^5
$> 3.9 \text{ MeV}$	6.46×10^2	$6.8 \times 10^{2*}$	1.25×10^2	77.6	$1.7 \times 10^2 (> 3.6 \text{ MeV})$

-7-

* Day 90, 76 - 214, 76 only

V. Effects of the Interplanetary Medium on Energetic Electrons

We had earlier discovered (Ref. 14) that the flux level of the energetic electrons at the synchronous orbit - and therefore presumably the flux of energetic electrons in the entire outer magnetosphere - was modulated by the passage of the sector boundaries of the interplanetary magnetic field (IMF) past the earth. Briefly, we found that the flux levels were higher during northern hemisphere fall when the earth was immersed in a positive sector than during the passage of a negative sector of the interplanetary magnetic field. Conversely, in the spring, negative sectors served to generate higher energetic electron fluxes. This finding was found to be in agreement with the picture of solar wind-magnetosphere interaction proposed by Russell and McPherron (Ref. 17).

The findings described above were based on a very limited set of data. In the past year we have attempted to confirm and extend our conclusions using the more than 2½ years of data presently available. The relevant points can be seen by examining Figures 2-5, where we have plotted the daily averages of the energetic electron fluxes, together with the sector structure of the interplanetary field (see the caption of Figure 2 for explanation of IMF data presentation). It can be seen from these figures that the sector structure of the interplanetary field provides the dominant modulation of electron fluxes. Our conclusion that higher fluxes result in the fall from + sectors than from - sectors (and that the converse holds true in the spring) can be verified by inspection of these figures. We are now in the process of trying to assess more quantitatively the relationship between the vector of the interplanetary field and the velocity of the solar wind and the generation of energetic particles in the magnetosphere.

This study, if successful, may lead to techniques for the quantitative prediction of the energetic electron fluxes at the synchronous altitude, using as input solar wind and IMF data. It appears that using data on the local (i.e. near earth) solar wind, radiation fluxes could be predicted several days in advance because of an apparent time lag between changes in interplanetary conditions and the generation by magnetospheric processes of energetic electron fluxes. Should our knowledge of solar physics, i.e. our understanding of the structure and properties of coronal holes and the

solar wind advance sufficiently, then solar data, coupled with an appropriate understanding of interplanetary transport processes, might enable radiation predictions to be made of the order of a week ahead of time.

We mention this potential benefit, because it is clear that in the future, applications spacecraft of many varieties are likely to proliferate in the synchronous orbit (see Refs. 1 and 2, for example), and modest advances in radiation prediction - particularly for manned spaceflight applications, may yield extremely beneficial results.

VI. Future Work

We plan to update and revise this report as additional ATS-6 data are reduced and analyzed. At the time of writing (August 1977) the experiment continues to function well. With luck (and NASA's continued interest) ATS-6 will cover the rising portion of the solar activity cycle and provide unique data in this respect.

In addition, we plan to analyze ATS-1 data, which were acquired simultaneously with ATS-6 during portions of 1974, 1975 and 1976. The comparison between data from spacecraft fixed in longitude (ATS-1) and the ATS-6 which sampled a range of longitude should provide definitive information of the variation of the properties of the electron radiation with longitude at the synchronous orbit.

VII. Acknowledgments

The ATS-6 experiment which yielded the results described in this report was developed with the able assistance of Sam Imamoto and Gloria Roberts. The data reduction efforts were handled by Doretha (Ross) Mayfield. This work was carried out as part of the program of Mission Oriented Investigations and Experimentation supported at The Aerospace Corporation by the USAF Space and Missile System Organization under Contract No. F04701-76-C-0077. Portions of the data reduction efforts were supported by NASA under Contracts NASW-2762, NASW-2879 and NAS5-23788.

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Figure Captions

- Figure 1. Relationship between the intervals of data acquisition on energetic electrons at synchronous altitudes by experiments on board ATS spacecraft and the 11-year solar activity cycle as defined by the Zurich sunspot number
- Figure 2. Daily average fluxes for 1974 for the four channels of ATS-6 electron data. The trace at the bottom of each panel gives the sector structure of the interplanetary magnetic field as determined by Svalgaard (Ref. 16). Positive sector days are indicated by the upper line, negative sector days by the lower line. Days when polarity is mixed are indicated by a point falling between the two lines.
- Figure 3. Same as Figure 1, except for 1975. The data for the > 3.9 Mev channel are suspect after Day 140, 1975 and have been deleted.
- Figure 4. Same as Figure 1, except for 1976. The data for the > 3.9 Mev channel are suspect between Day 1 and Day 90 and have been deleted.
- Figure 5. Same as Figure 1, except for 1977. Isolated days of data are indicated by unconnected points.
- Figure 6. Running 27 day average electron fluxes for the four channels of ATS-6 energetic electron data obtained in 1974. Interplanetary magnetic field sector structure is indicated on each panel of data (see Fig. 2 caption for explanation).
- Figure 7. Same as Figure 7, for 1975. $E > 3.9$ Mev data after Day 140 is suspect and have been deleted.
- Figure 8. Same as Figure 7, for 1976. $E > 3.9$ Mev data between Day 1 and Day 90 are suspect and have been deleted.
- Figure 9. Same as Figure 7, for 1977.

- Figure 10. Normalized differential probability $P(F)$ of observing a flux F_x for the four ATS-6 electron channels during the interval Day 165, 1974 to Day 140, 1975 when ATS-6 was located at 94°W . This figure was constructed by sorting the observations into bins 0.1 wide in $\log_{10} F_x$. Data for all local times are included. The electron energies are E1: 140-600 keV, E2 > 700 keV, E3 > 1.55 MeV and E4 > 3.9 MeV. The units of F_x are $\text{cm}^{-2}\text{sec}^{-1}$ for all channels except E1 where the units are $\text{cm}^{-2}\text{sec}^{-1}\text{sr}^{-1}$ instead. The notation "ALL" on the figure indicates that all polarities of the interplanetary magnetic field are included in this analysis. The column U gives the mean of the logarithms of the (hourly average) fluxes during this interval, the column J gives the logarithm of the mean flux and S is the logarithm of the standard deviation from U.
- Figure 11. The data of Figure 10 are presented as integral probabilities $P(F > F_x)$ of observing a flux greater than F_x during the Day 165, 1974 to Day 140, 1975 time interval. All other comments apply.
- Figure 12. Same as Figure 10, except the time interval is Day 180, 1975 to Day 214, 1976 where ATS-6 was located at 35°E . The E4 curve contains data from the interval 90, 76 to 214, 76.
- Figure 13. The data of Figure 12 are presented as integral probabilities of observing a flux greater than F_x during the Day 180, 1975 to Day 214, 1976 time interval. All other comments apply.
- Figure 14. Same as Figure 10, except the time interval is Day 330, 1976 to Day 120, 1977 where ATS-6 was located at 140°W . The prominent peak in E4 near an apparent flux of $\approx 10 \text{ cm}^{-2}\text{sec}^{-1}$ is due to the galactic cosmic ray background (see Appendix A) because the energetic electron flux was very low during this time period -see Figures 4, 5, and 8, 9.
- Figure 15. The data of Figure 14 are presented as integral probabilities of observing a flux greater than F_x during the Day 330, 1976 to Day 120, 1977 time interval. All other comments apply. Note that for a flux of $< 15 \text{ cm}^{-2}\text{sec}^{-1}$ in the E4 channel all "electrons" are really galactic cosmic rays or their products.

- Figure 16. Electron energy spectra constructed using the average fluxes for each time interval indicated. The fluxes measured in the 140-600 keV directional channel have been multiplied by 4π to obtain a measure of the omnidirectional flux in this energy interval. The $E_e > 3.9$ Mev point associated with the Day 180, 1975 to Day 214, 1976 curve was obtained using data from the Day 92, 1976 to Day 210, 1976 interval.
- Figure 17. Diurnal variation of the average electron flux observed during the time interval Day 165, 1974 - Day 140, 1975 when ATS-6 was located at 94°W .
- Figure 18. Same as Figure 17, except that the time interval is Day 180, 1975 to Day 214, 1976 when ATS-6 was located at 35°E . The E4 channel is not shown.
- Figure 19. Same as Figure 17, except that the time interval is Day 330, 1976 to Day 120, 1977. ATS-6 was at 140°W at this time.

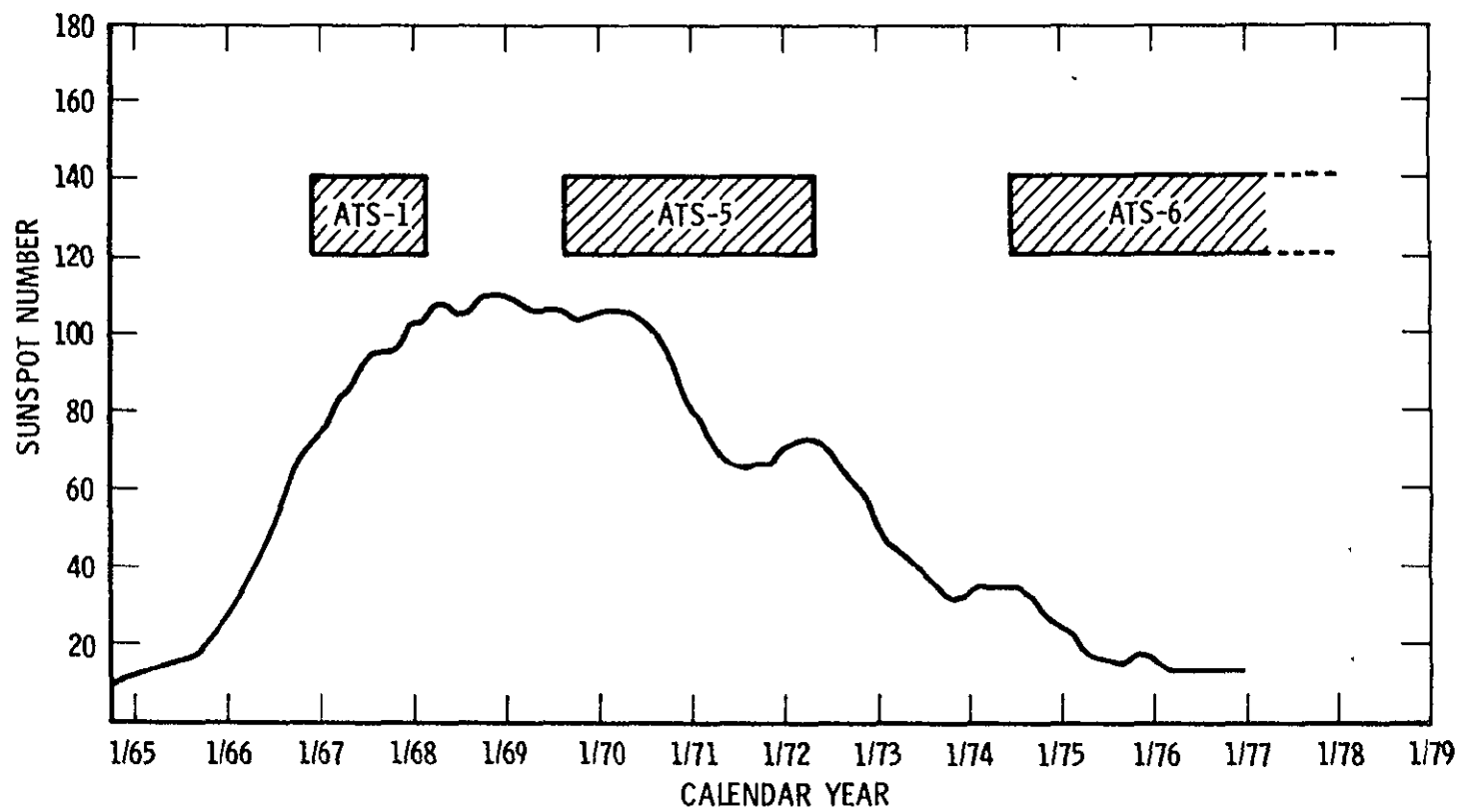


Fig.
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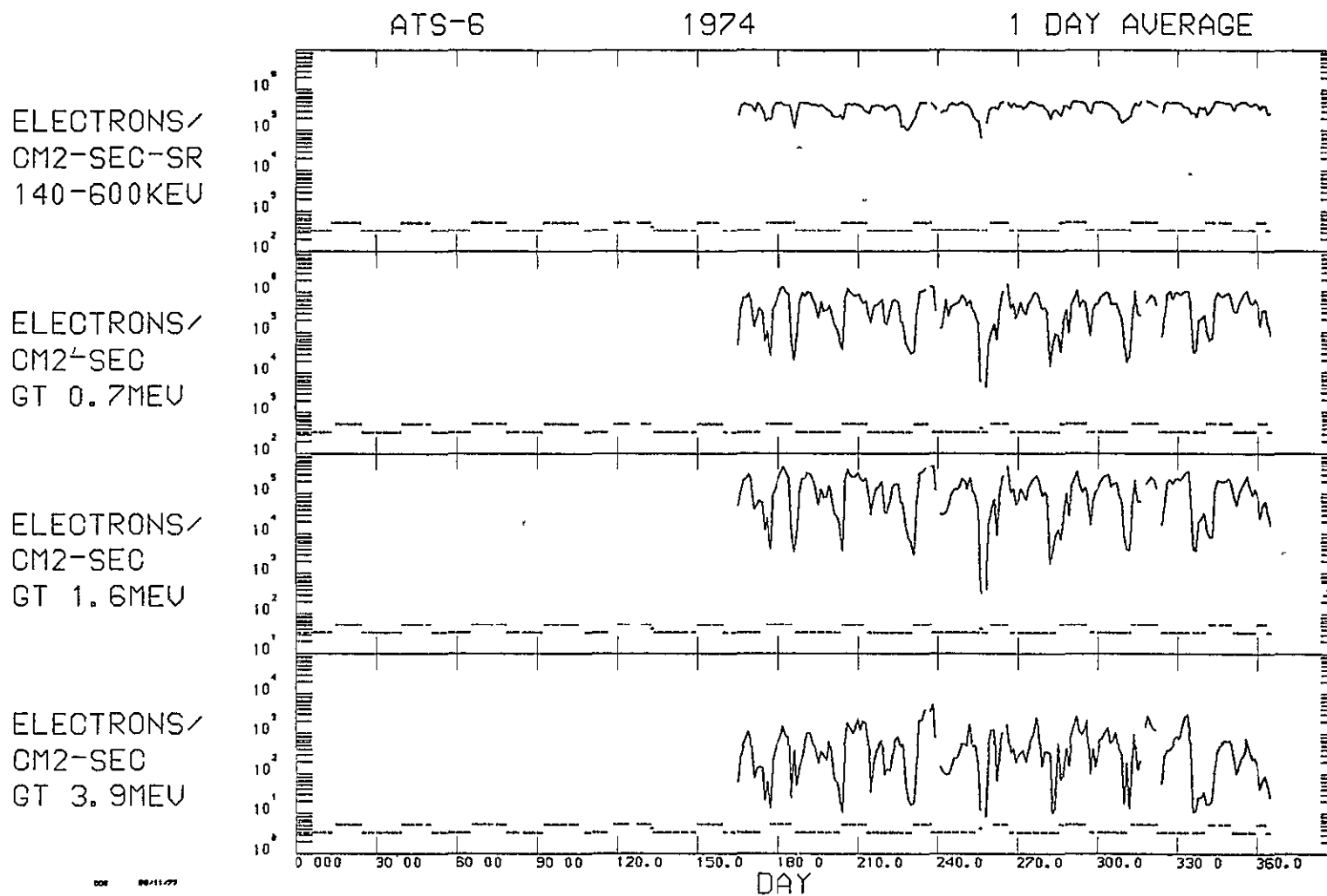


Fig.
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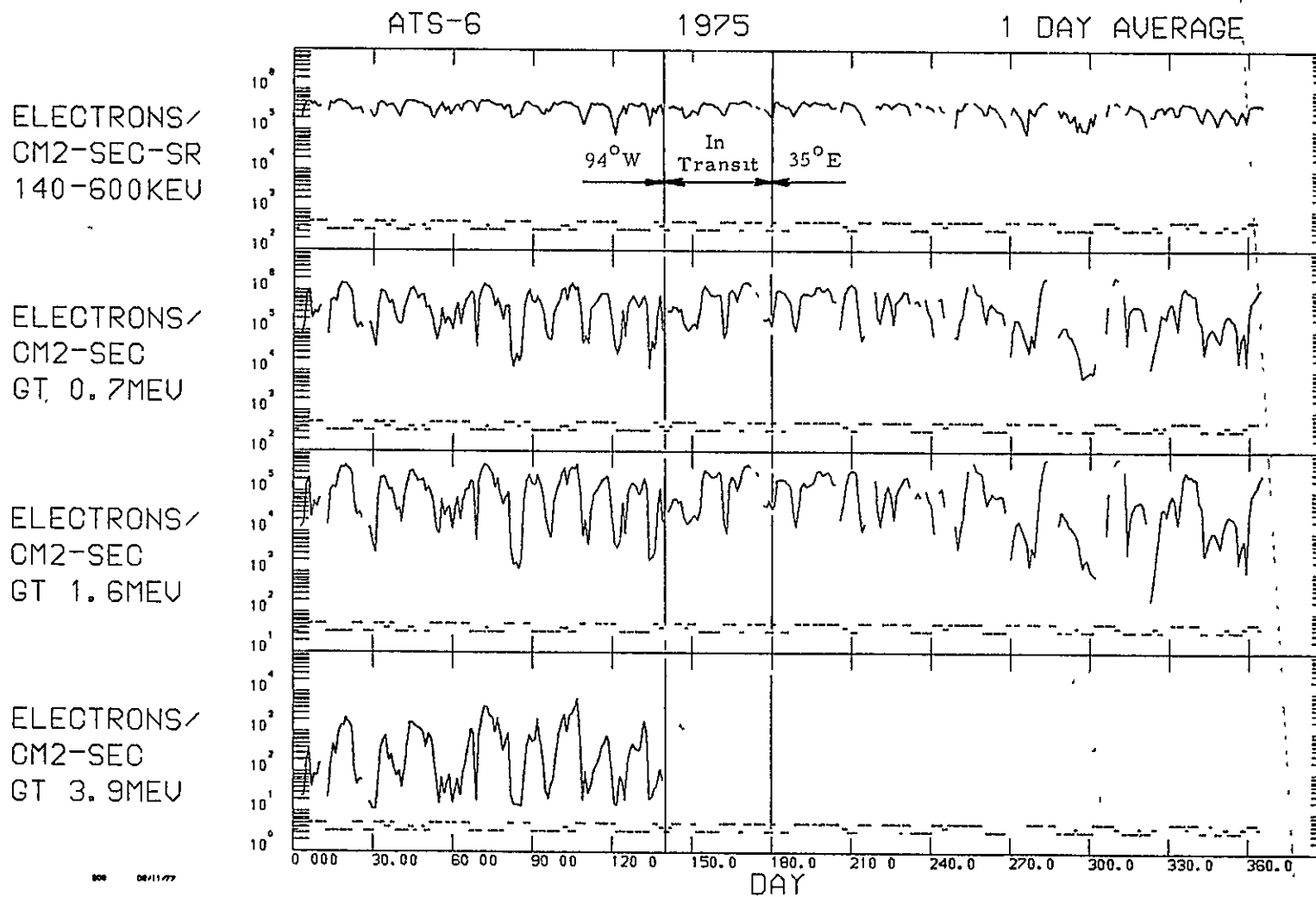


Fig.
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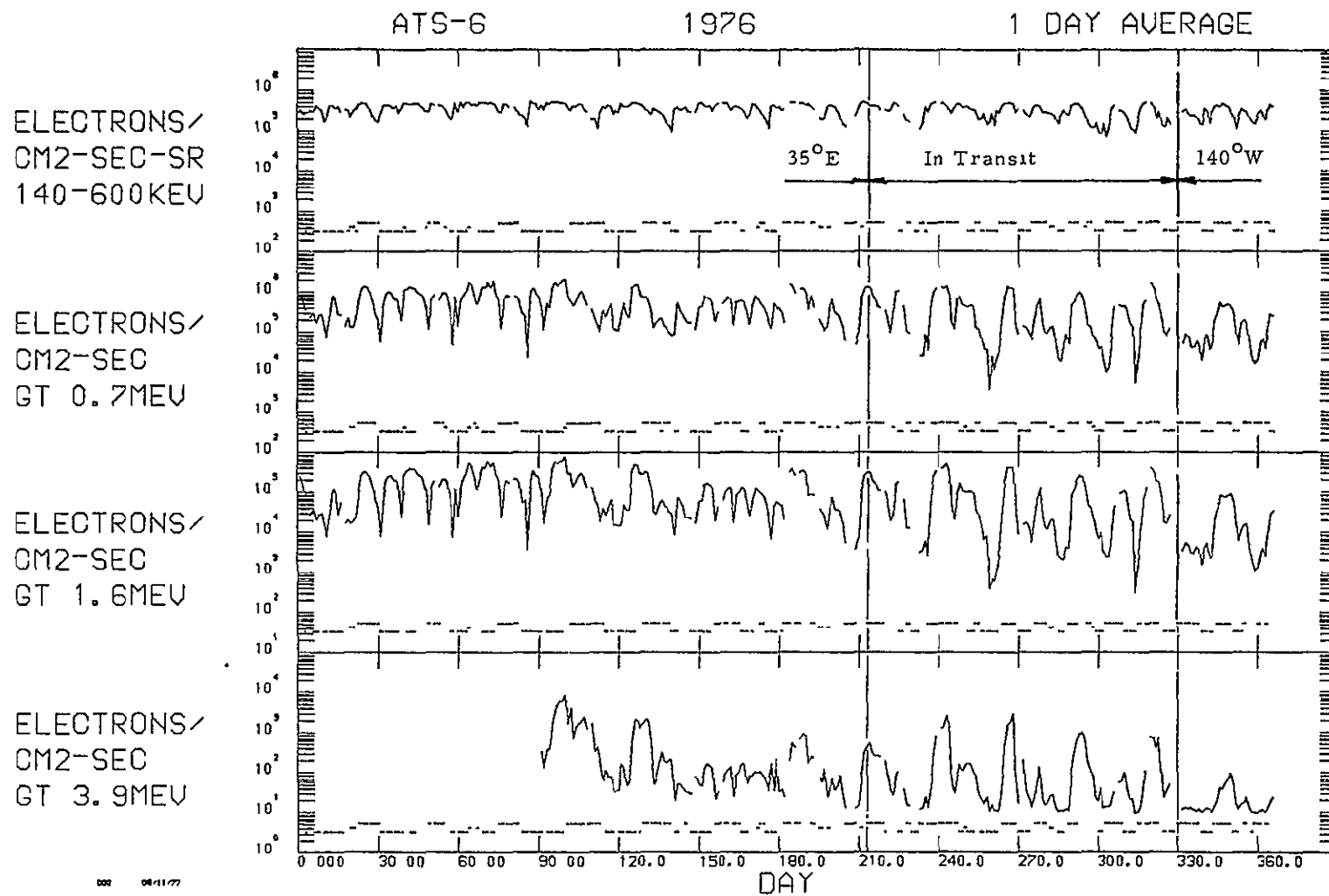


Fig.
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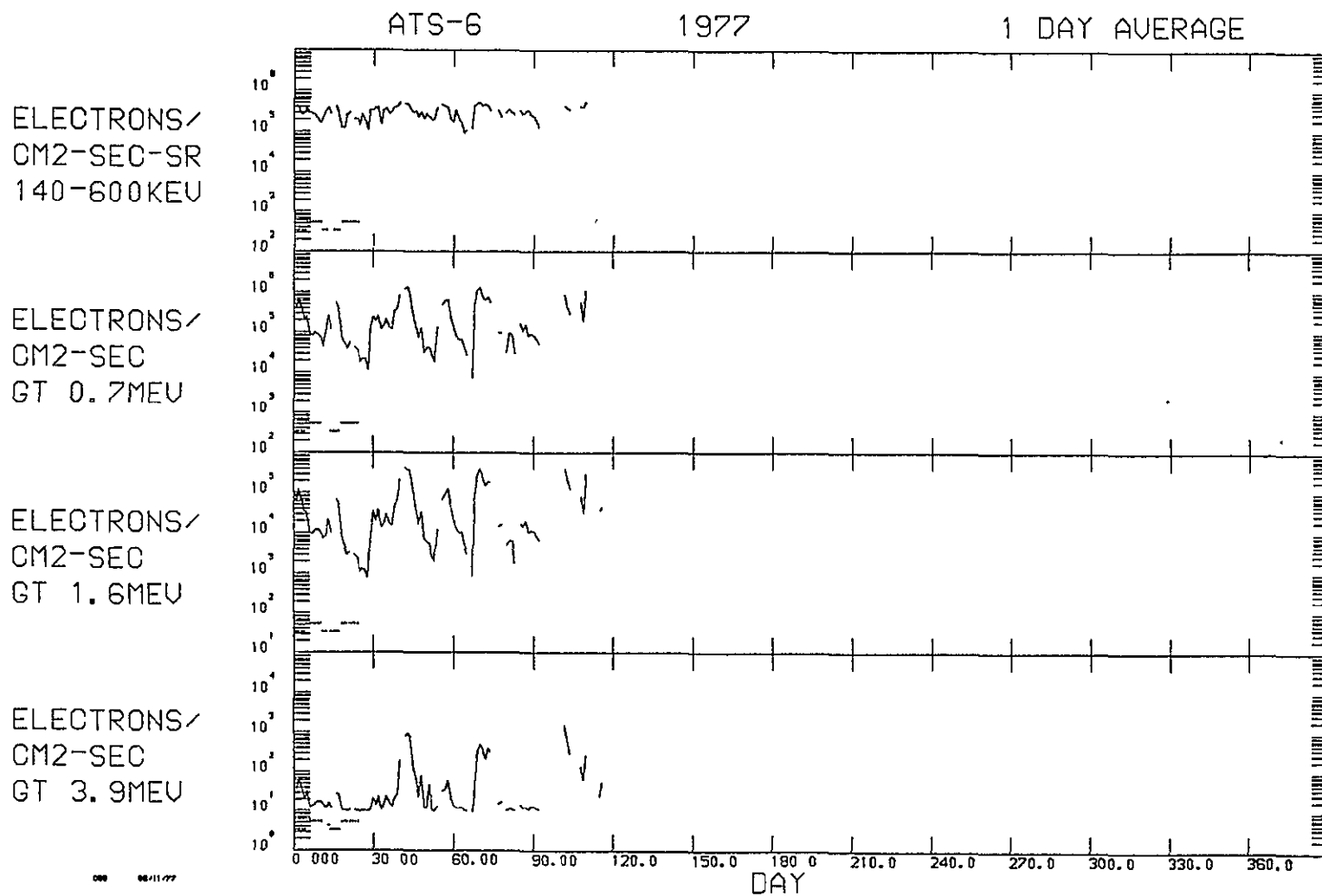


Fig.
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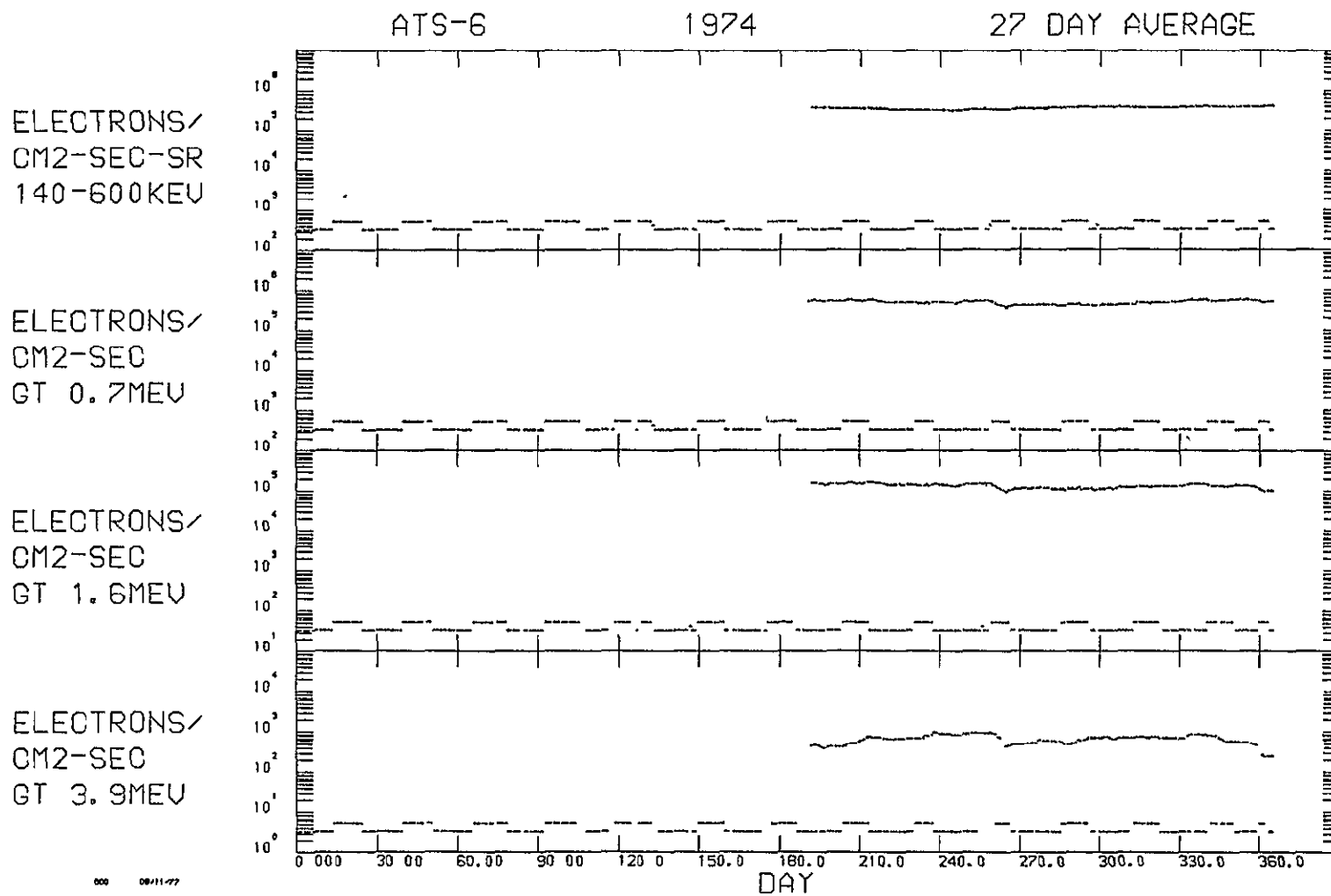


Fig.
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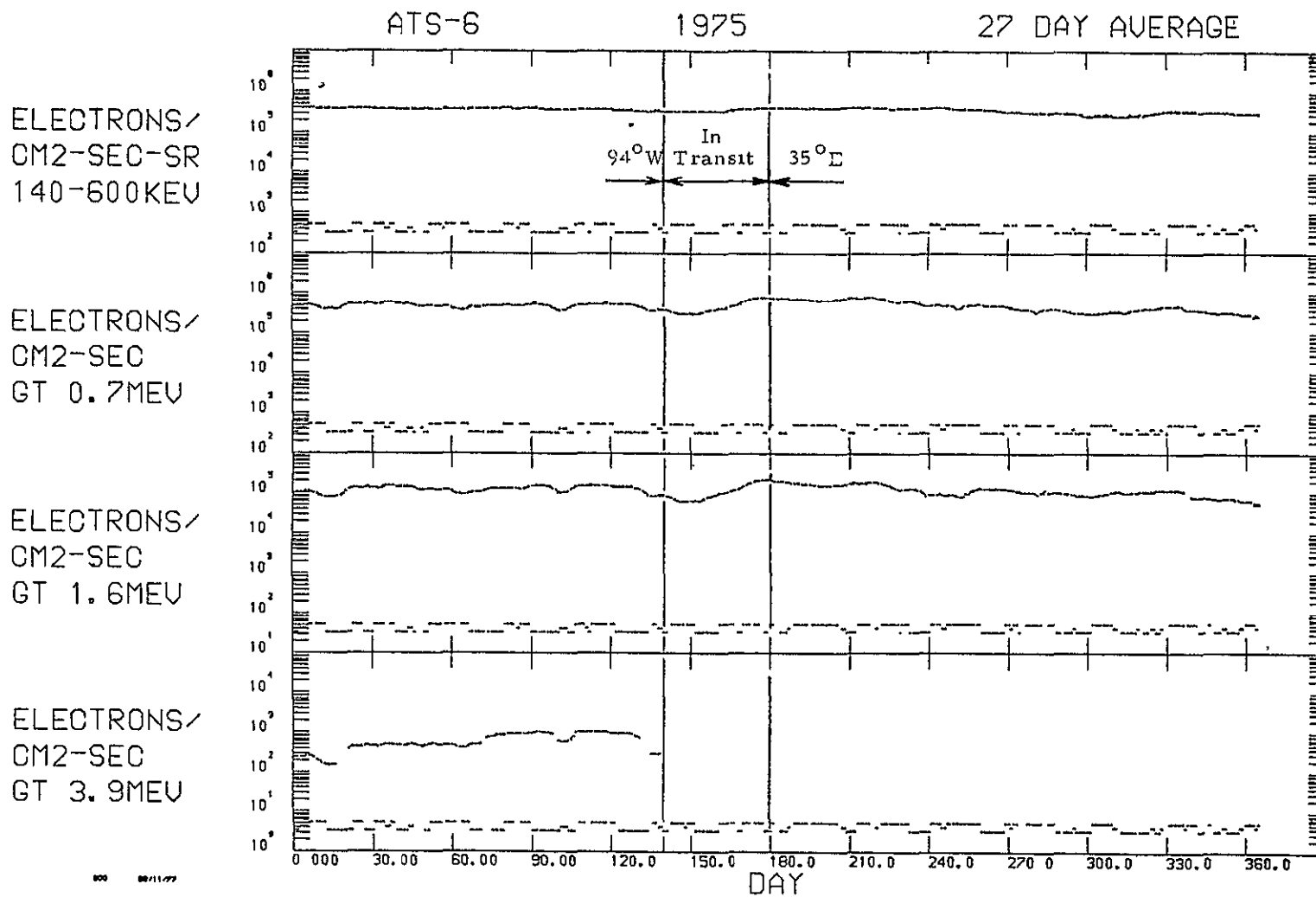


Fig.
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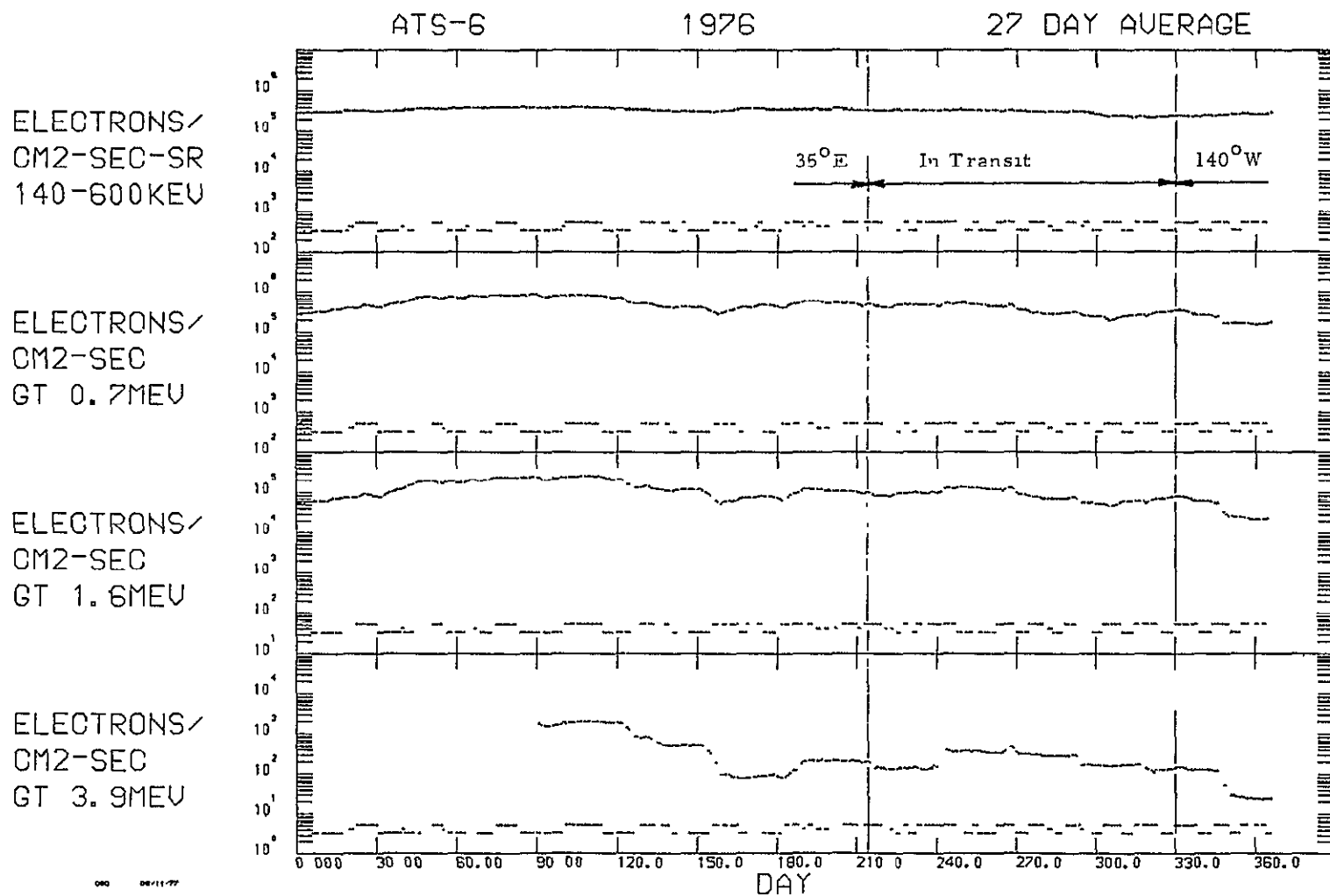


Fig.
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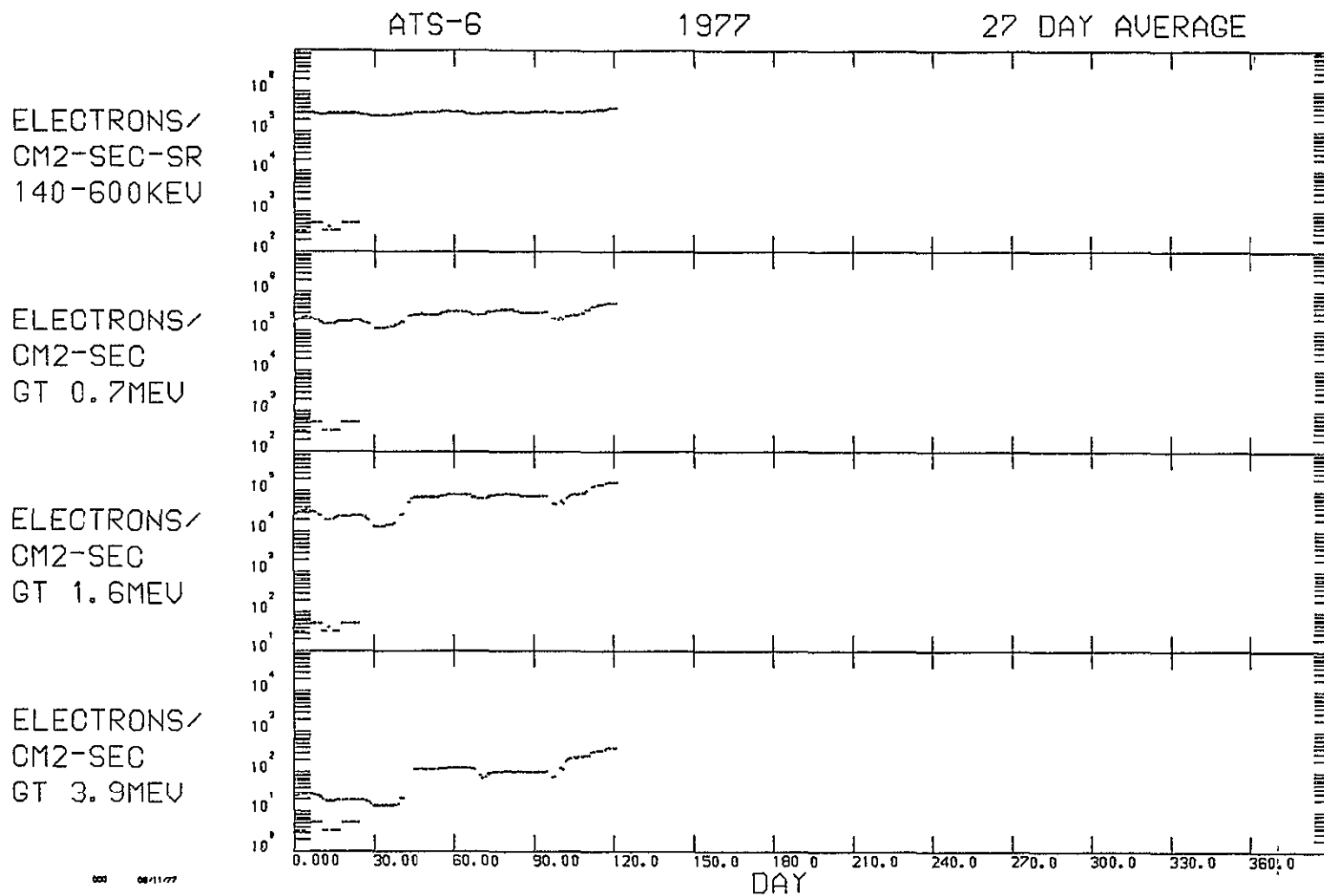


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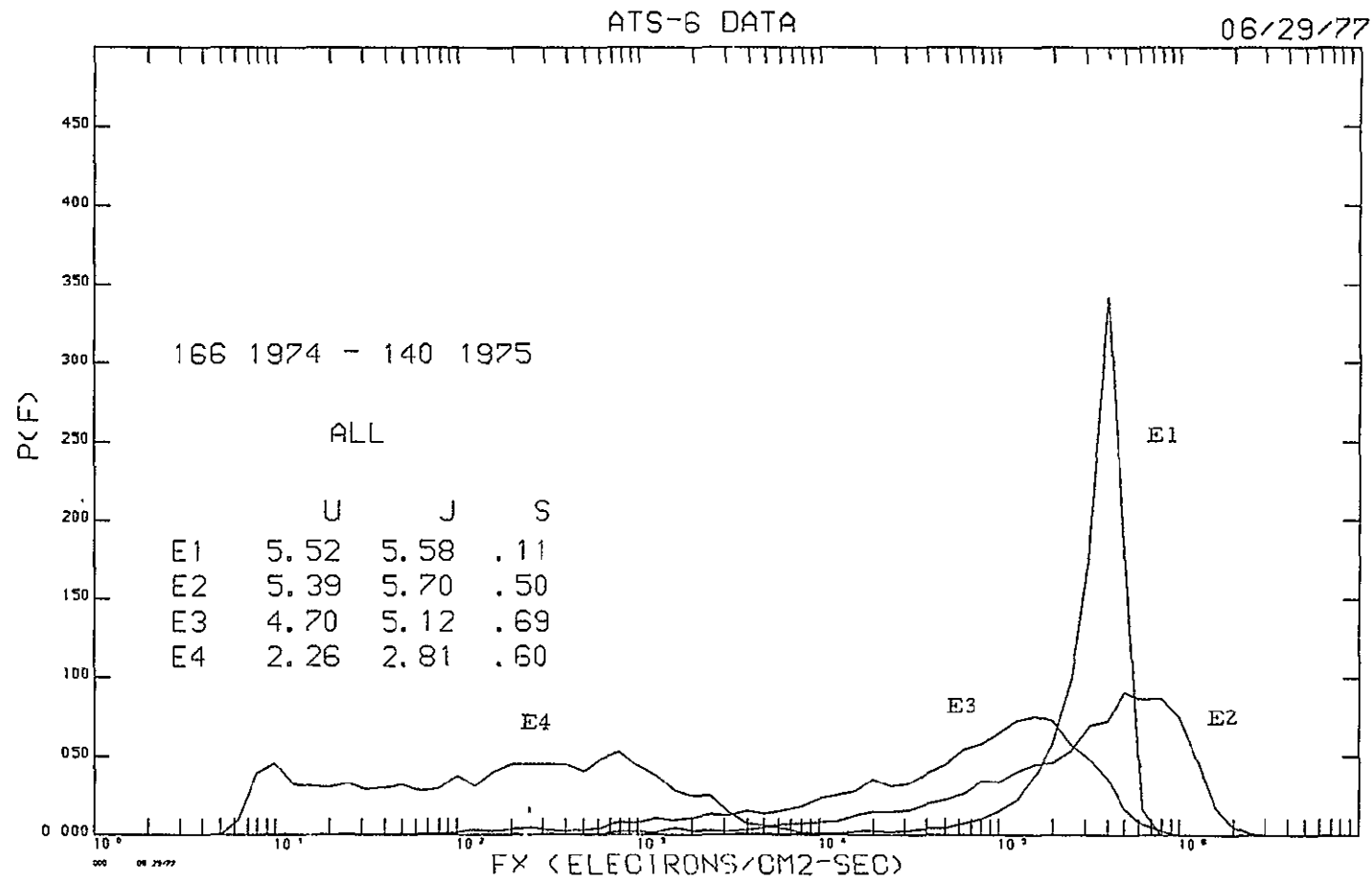


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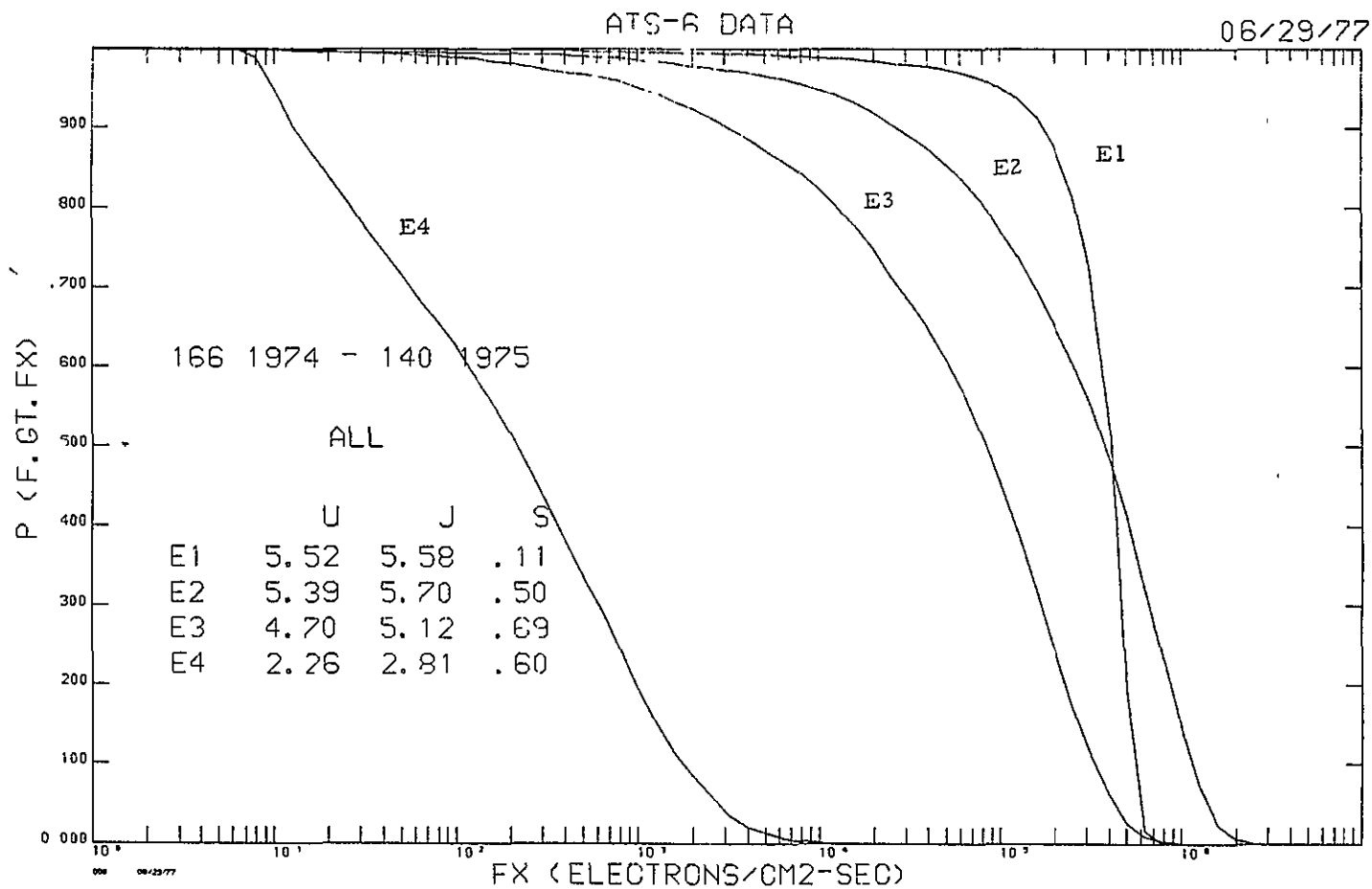


Fig.
11

ATS-6 DATA

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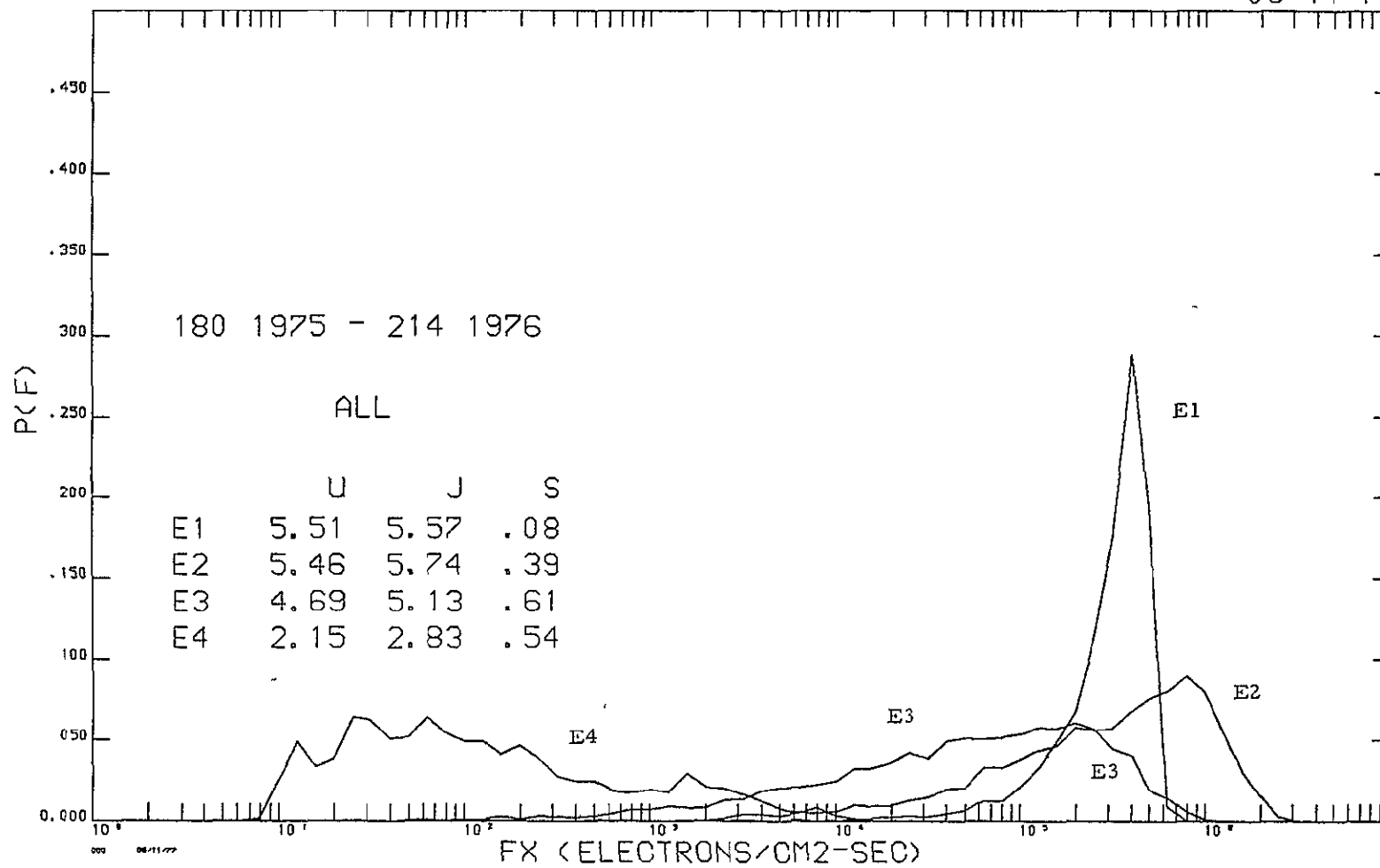


Fig.
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ATS-6 DATA

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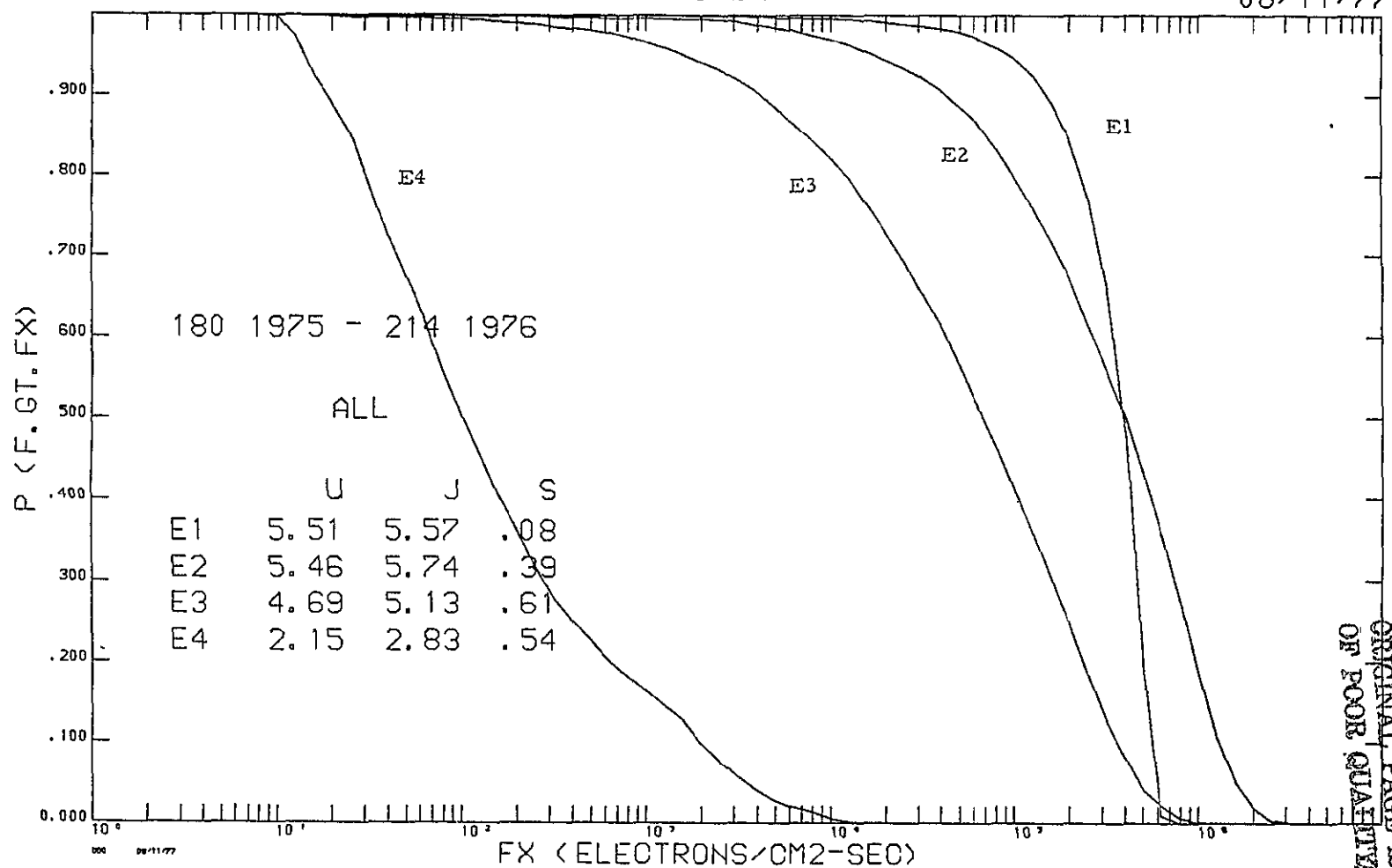


Fig.
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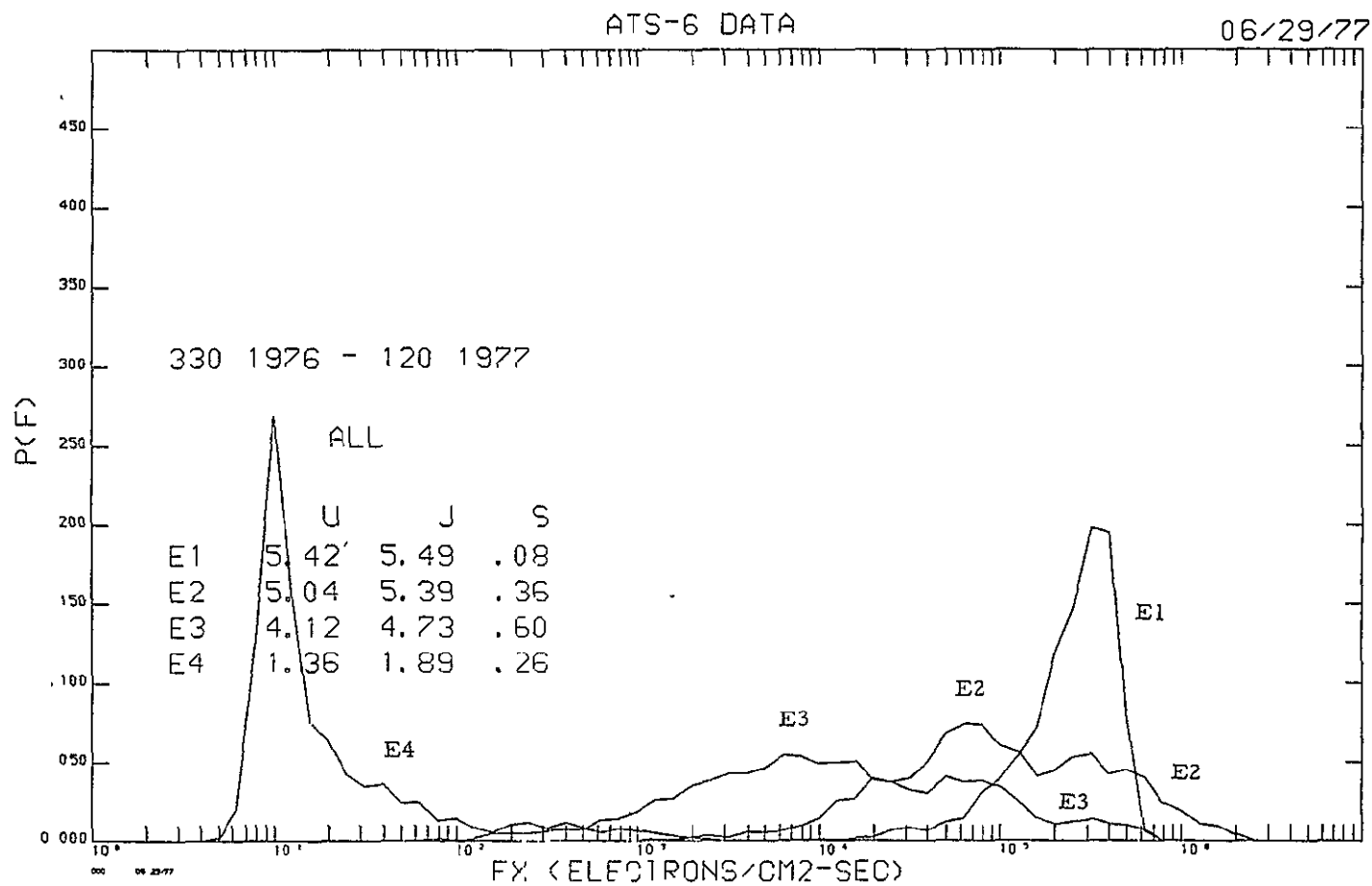


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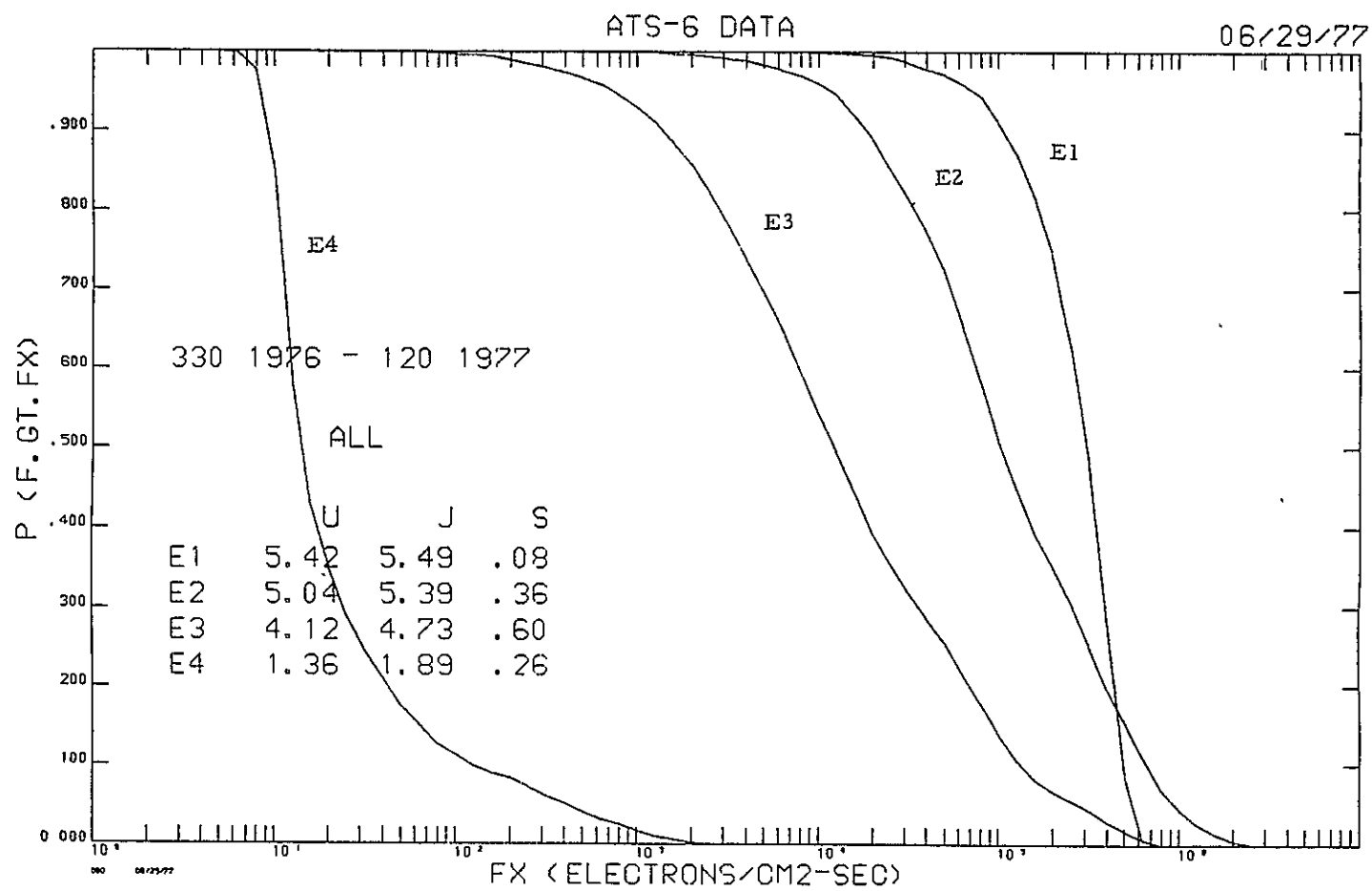


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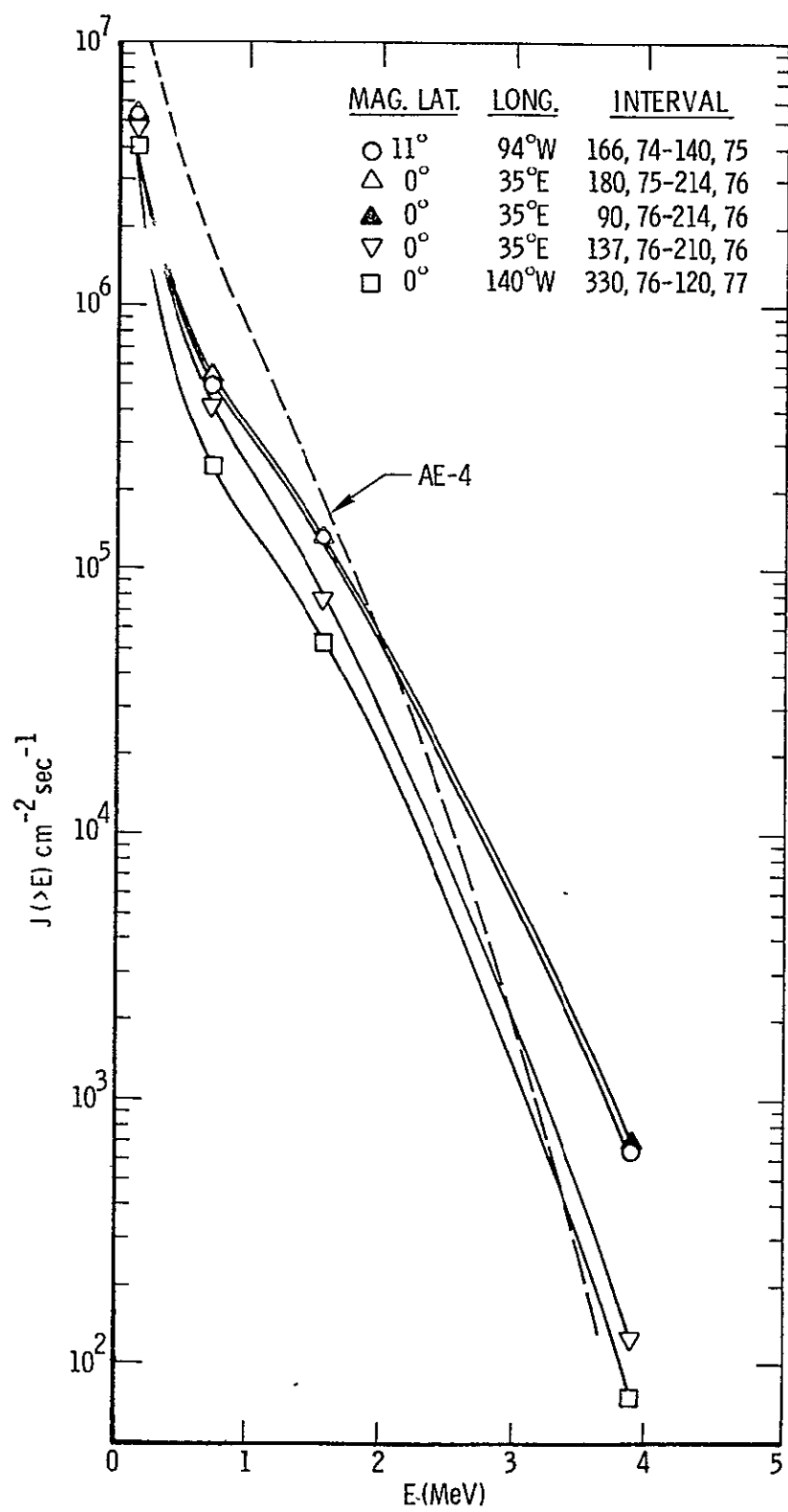


Fig.
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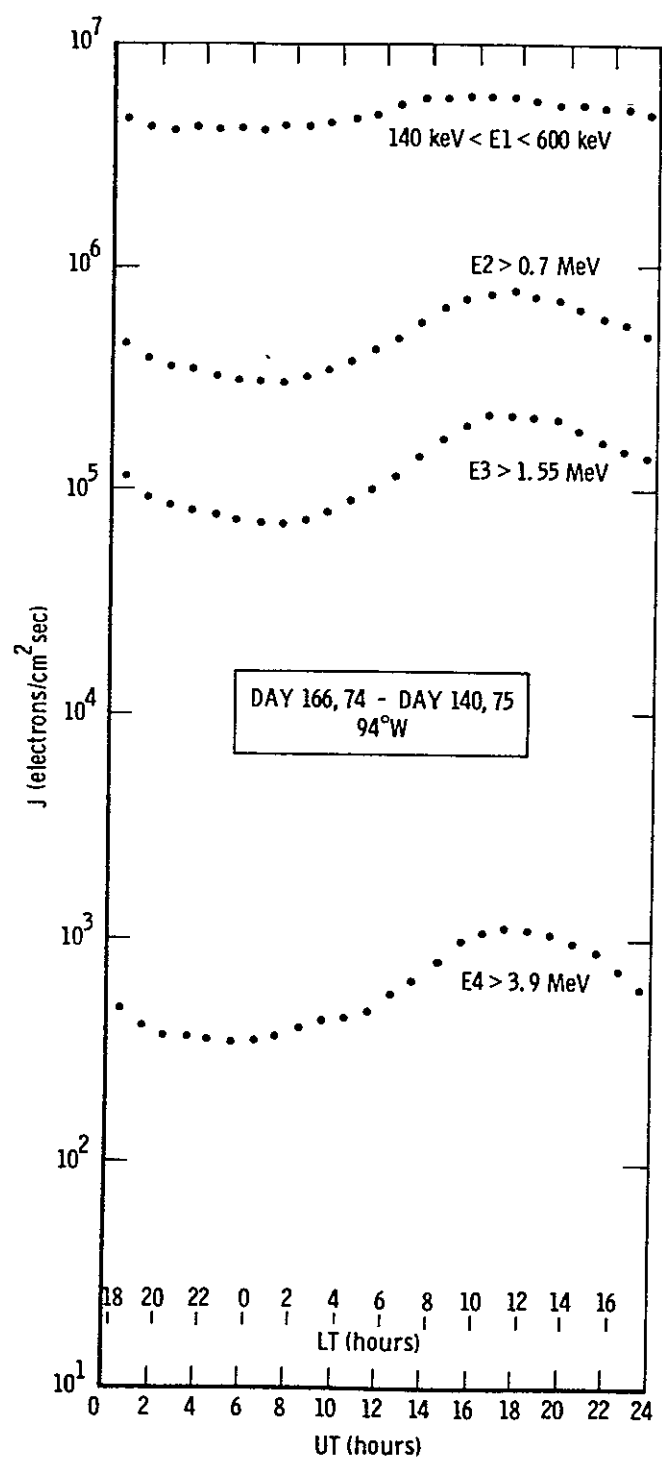


Fig.
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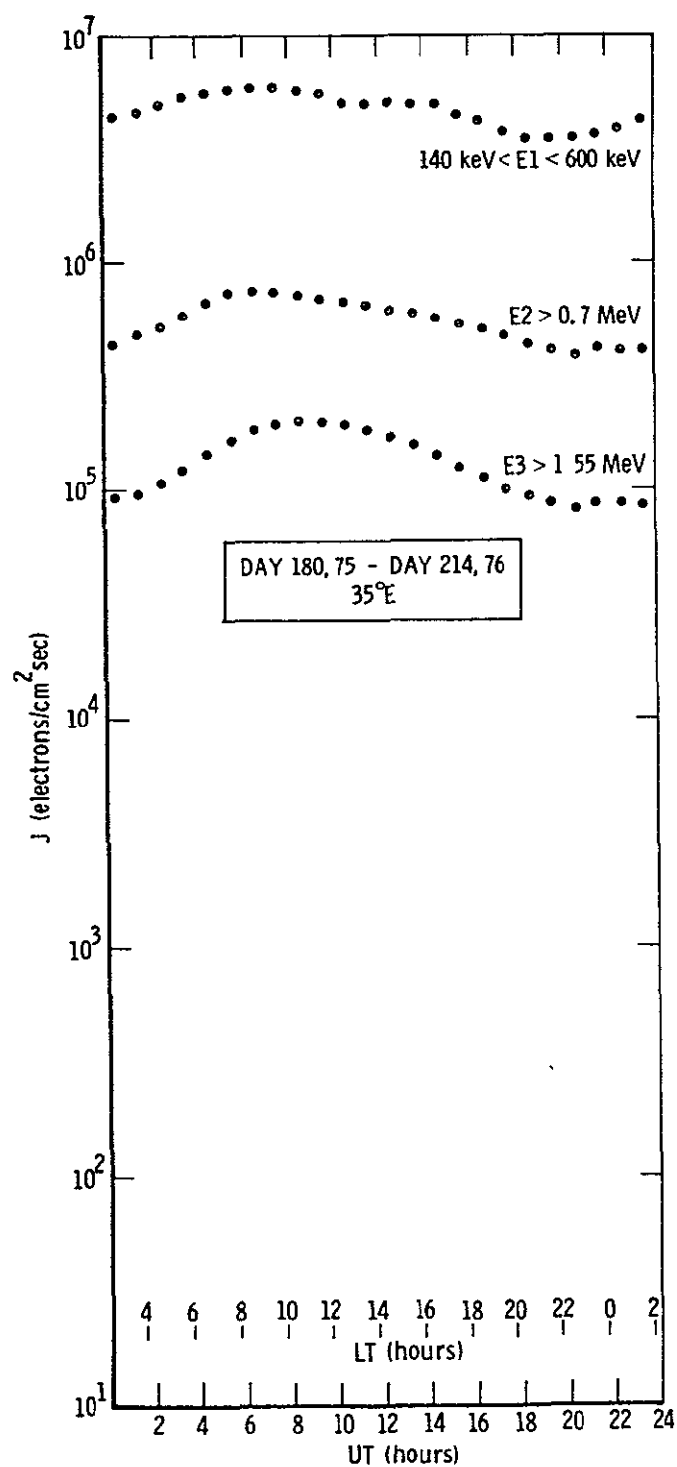


Fig.
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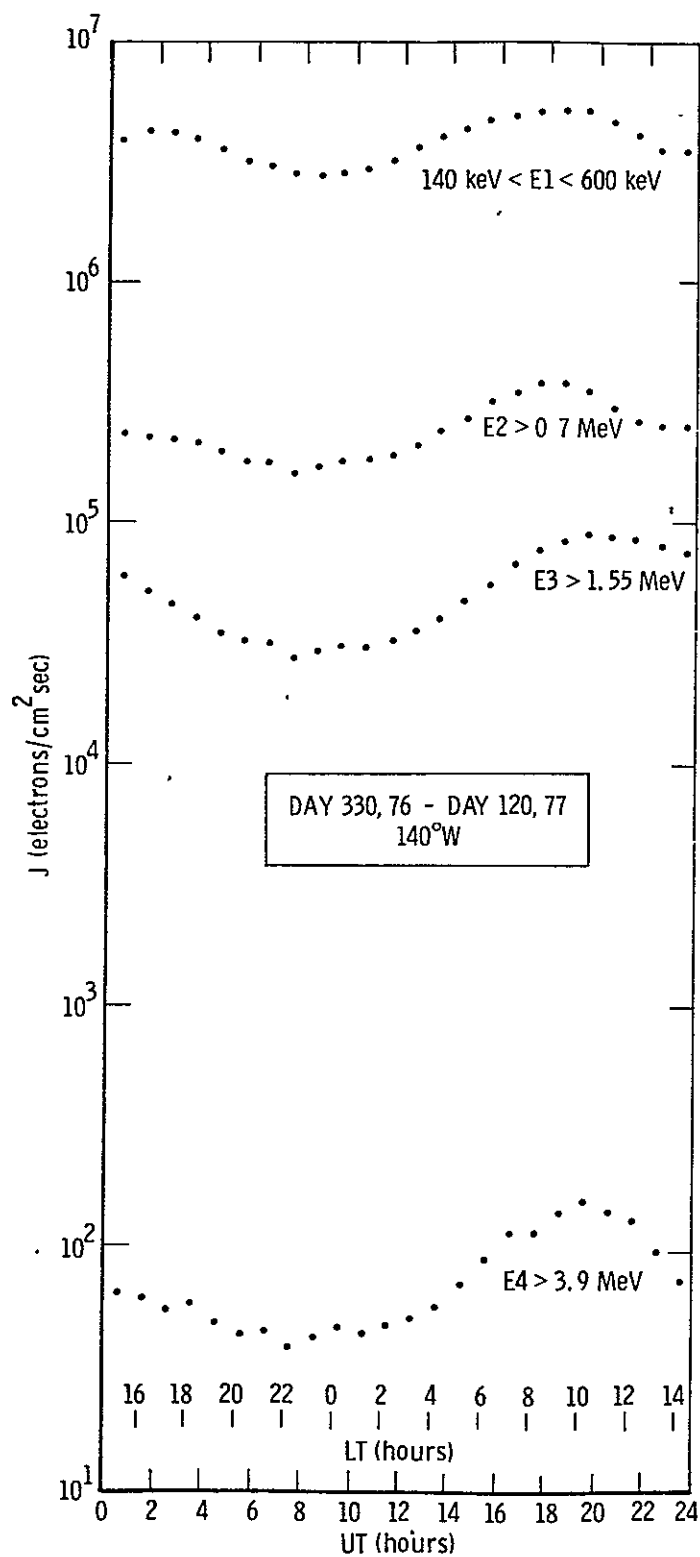


Fig.
19

Appendix A: A Description of Instrument Response

A full description of the ATS-6 Aerospace Corporation experiment has been presented in Ref. 13. Here we summarize, for ready reference, those salient features of the instrument response which may be of interest or assistance in interpretation of the results presented in earlier portions of this report.

Instrument Description

Figure A-1 shows a schematic block diagram of the detector/electronic system. The electron channels, E1, E2, E3, E4 are derived from Sensors 1-4 respectively. Figure A-2 shows the experiment.

Electron Detection

The responses of the electron channels are illustrated in Figures A-3 and A-4 respectively. These data, integrated over the angular acceptance angles of each detector give the average detector geometric factor as a function of energy. It has proven convenient to integrate these energy dependent geometric factors over various (assumed) shapes of the incident electron spectrum and finding a threshold (or set of thresholds for the E1 channel) which minimizes the variation of the geometric factor with spectral shape. The results are presented in Table A-1. The G factors given in this table were used to convert from counts to flux above the indicated thresholds (or, for E1, in the indicated energy interval).

Proton Contamination

Proton channels which measure trapped and solar proton fluxes are also associated with each detector. In principle, the proton data can be used to correct for any proton contamination of the electron data. In practice, we found that during the 1974-1977 interval, solar proton activity was very low and no systematic correction was required; instead, days of data where some solar proton contamination (primarily of the E3, E4 channels) was suspected were rejected from the analysis. The sporadic fluxes of low energy (several Mev) trapped protons which we occasionally observed did not have any effect on the electron channels. Galactic cosmic rays and the products generated by their interaction with the spacecraft gave

rise to a significant background in the E4 channel. This background has a diurnal signature characteristic of cosmic rays (i.e. a maximum near local midnight and a minimum near local noon). During time periods when the trapped electron flux was low, for example the late 1976 - early 1977 time period, this background can be clearly visible in the E4 data (see Fig. 5) as an apparent flux of $\approx 10 \text{ cm}^{-2}\text{sec}^{-1}$. The true flux is more likely $\approx 5 \text{ cm}^{-2}\text{sec}^{-1}$ because the geometric factor of the E4 channel for these very energetic, minimum ionizing particles is a factor of two larger than quoted in Table A-1. This background has not been subtracted from our results; although of galactic origin, the radiation masquerading as "energetic electrons" is always present at the synchronous orbit, is practically indistinguishable from energetic electrons, and may be of some practical consequence as an ever-present background.

Bremsstrahlung Effects

During our calibrations, the bremsstrahlung efficiencies of the E2, E3, E4 channels were measured. Upper limits for the efficiencies were determined; those upper limits fall well below 10^{-4} relative to the direct detection of electrons. In all cases, we find that the galactic cosmic ray background exceeds that which might be generated by bremsstrahlung.

Accuracy of Results

The dominant source of error in this experiment arises because of the uncertainty, estimated to be $\approx 20\%$, in the geometric factors. All other experimental sources of error are minimal. While, under some circumstances, counting statistics may contribute additional uncertainty, in this paper we are dealing with long term flux averages which effectively eliminate counting statistics on an error source. It is important to reiterate that our measurements deal with a high variable phenomenon characterized by significant deviations from the mean. Comparisons of our results with those of others need to take this into account and also recognize that important long term effects (related to the 11 year solar cycle) in the structure of the radiation belts exist.

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TABLE A-1
Omnidirectional Geometric Factors

Channel	Passband or Threshold (Mev)	ϵ_G
E1	0.140-0.600	$0.115 \text{ cm}^2_{\text{sr}}$
E2	0.700	0.00349 cm^2
E3	1.55	0.0176 cm^2
E4	3.90	0.0688 cm^2

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Appendix Figure Captions

- Figure A-1 Schematic block diagram of detector/electronic system.
- Figure A-2. Overall view of the energetic particle spectrometer on ATS-6. Directional detectors (E1 channel) are housed inside the cylindrical collimator structure in the foreground.
- Figure A-3. Efficiency of detection of electrons in the E1 channel. This channel has a nominal energy sensitivity of 140-600 keV. Sensitivity of this channel below the nominal electronic threshold is associated with the finite noise of the detector.
- Figure A-4. Effective area of the E2, E3 and E4 electron channels as a function of electron energy. This effective area, when integrated over the angular response of the detector, yields the omnidirectional geometric factor. Bremsstrahlung efficiencies fall well below lower limits of this figure.

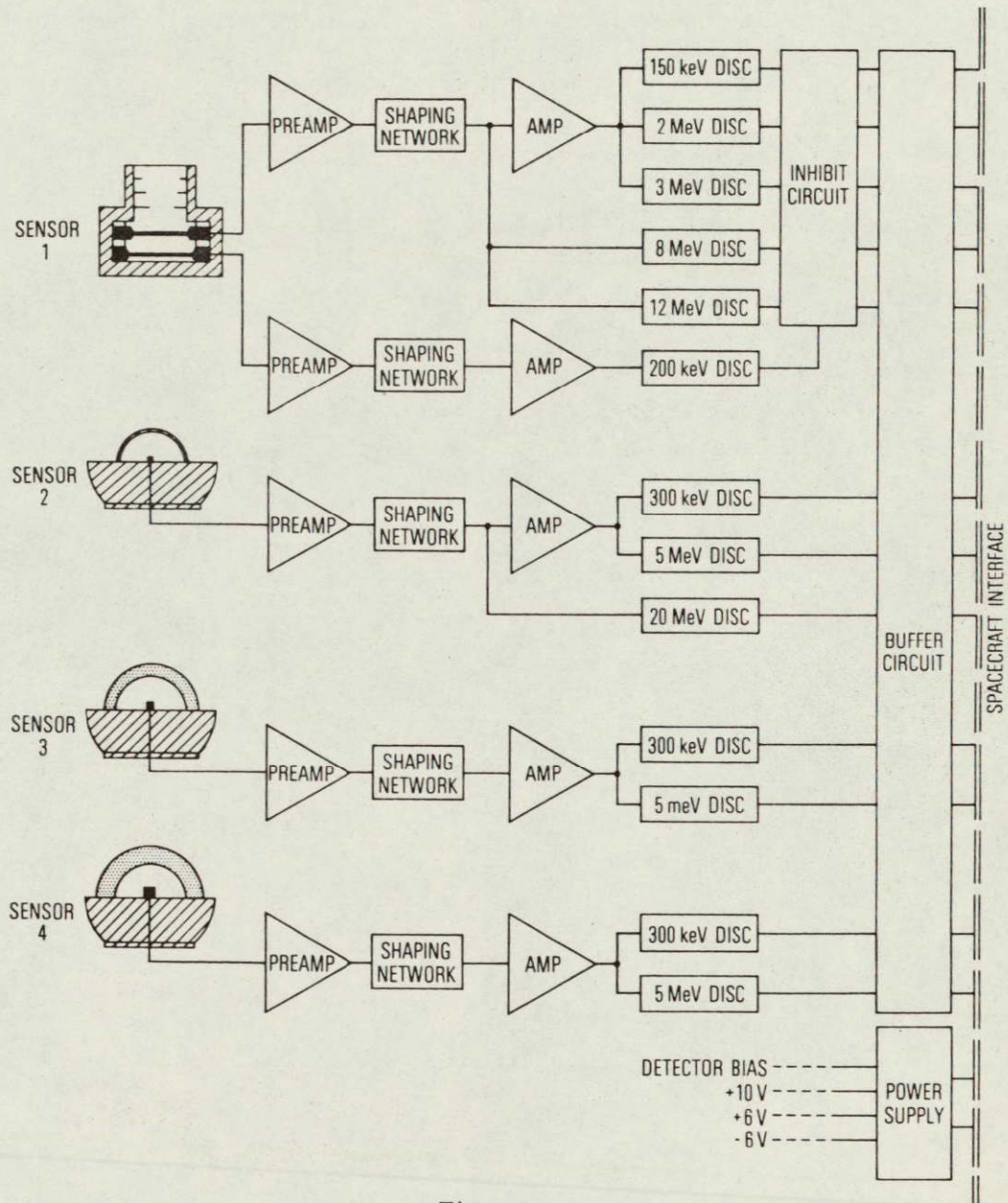


Fig.
A-1

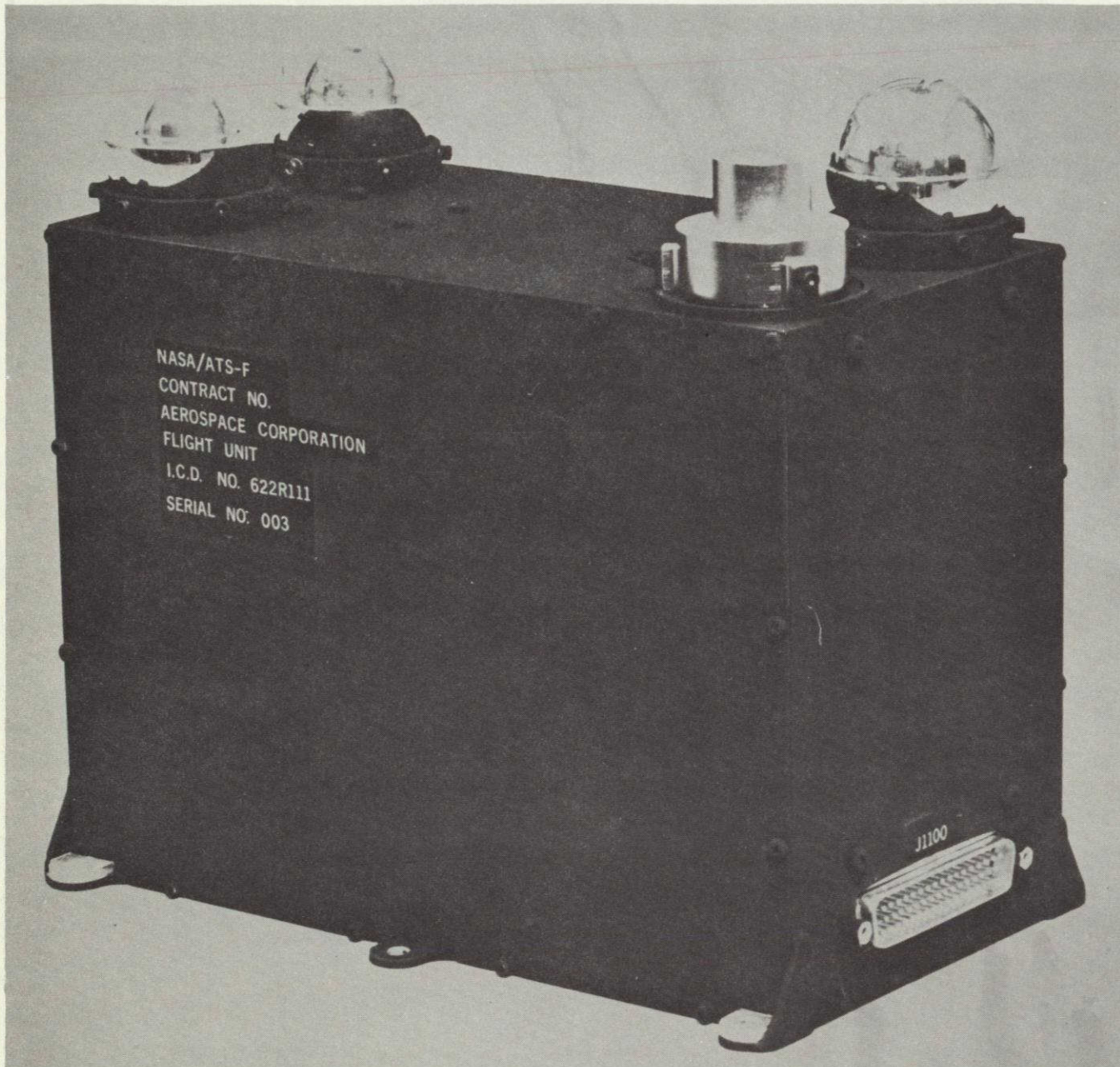


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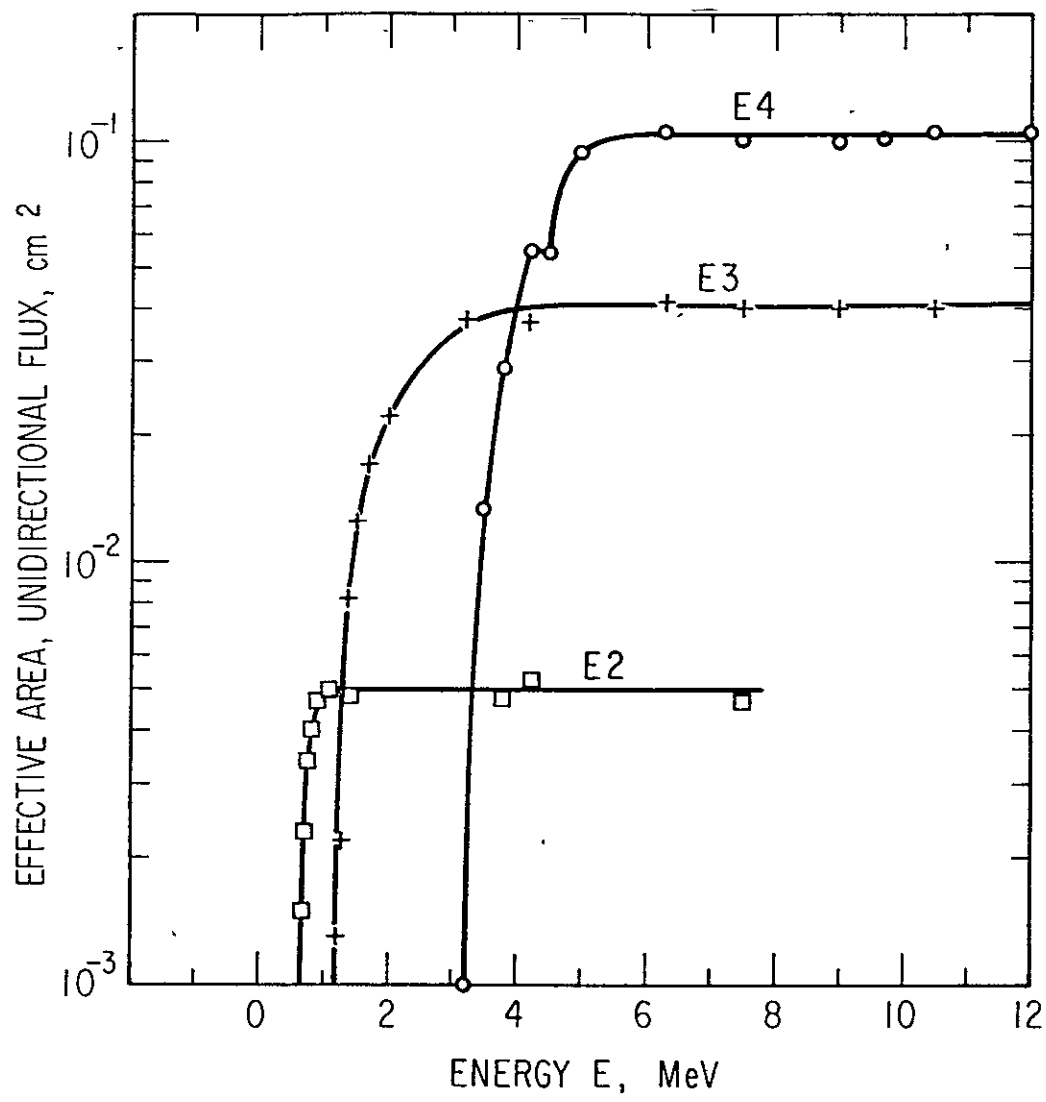


Fig.
A-4

